SUMMARY REPORT

SMALL HYDROELECTRIC DEVELOPMENT STUDY

NORTHWEST TERRITORIES

A Feasibility Study

86-05641/

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NORTHWEST TERRITORIES

A Feasibility Study

Prepared for:

Northern Canada Power Commission

Prepared by:

Hydrowest Consultants Inc.

With a contribution from:

Remote Community Demonstration Program
of Energy, Mines and Resources Canada

June 1985

RCDP/PDCE-76-A

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SUMMARY REPORT

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hydrowest consultants inc.
Mayfield Business Centre, 10512-169th Street, Edmonton, Alberta, Canada T5P 3X6
Telephone (403) 483-4777 Telex 037 414 32

June 14, 1985

Northern Canada Power Commission
7909-51 Ave.
P.O. Box 5700, Station L
Edmonton, Alberta
T6C 4J8

Attention: Mr. J.D. Allan, P.Eng.

Dear Mr. Allan:

Reference: Small Hydroelectric Development Study, N.W.T.
Summary Report

This report has been written especially for the use by the communities, and it is therefore simplified as much as possible in terms of technical language. However, it is felt that the basic objectives and findings of the study have been accurately presently.

We appreciated the opportunity to be of service on this challenging assignment.

Yours truly,

S.I. Ramsahoye
Project Manager
for Hydrowest Consultants Inc.

SIR/fl
Encls.

Acknowledgement

This Small Hydroelectric Development Pre-Feasibility Study was funded by Energy Mines and Resources Canada under the Remote Community Demonstration Program.

The purpose of the program is to promote the adoption of alternative energy supplies and to encourage energy conservation in remote communities.

The program is aimed specifically at power generation and space heating on the community scale. Its goal is to reduce dependence on oil and broaden awareness of more appropriate (and often locally available) renewable fuels, conservation methods and other practical alternatives.

During the course of this study there were a number of meetings and discussions between the consultant and a Study Management Committee (SMC). The SMC was instituted to monitor the progress of the study, and as it turned out, the SMC not only monitored, but was of assistance shaping the direction of the study. In addition, the members were of assistance to the Consultant in providing data and information on a number of matters. Appreciation is expressed to the members of the SMC who were:

J.D. Allan - Chairman, N.C.P.C.
L. P. Haberman - Energy, Mines and Resources (EMR)
J. Cumming - EMR
R. Spalding - Department of Indian and Northern Affairs

Special mention should be made of the contribution of Mr. Hubert (Boreal Ecology) in liaising with the Community and assisting with the implementation of the field work.

Finally, the Consultant wishes to acknowledge the assistance by the staff of the N.C.P.C. in Edmonton and in the Northwest Territories.

METRIC-IMPERIAL CONVERSION TABLE

TO CONVERT FROM IMPERIAL TO METRIC			TO CONVERT FROM METRIC TO IMPERIAL
Multiply by	Metric	Imperial	Multiply by
2,54	Centimetre (cm)	Inch (in.)	0,394
0,305	Metre (m)	Foot (ft.)	3,281
1,609	Kilometre (km)	Mile (mi.)	0,621
0,092	Square metre (m2)	Square foot (ft2)	10,763
0,836	Square metre (m2)	Square yard (yd2)	1,196
2,590	Square kilometre (km2)	Square mile (mi2)	0,386
0,404	Hectare (ha)	Acre (ac.)	2,471
0,028	Cubic metre (m3)	Cubic foot (ft3)	35,315
0,765	Cubic metre (m3)	Cubic yard (yd3)	1,308
1,233	Cubic decametre (dam3)	Acre-foot (ac-ft.)	0,811
4,546	Litre (L)	Gallon (gal.)	0,220
0,159	Cubic metre (m3)	Barrel-oil (bbl.)	6,29
0,454	Kilogram (kg)	Av. pound (lb.)	2,205
0,907	Tonne (t)	Ton (2000 lb.)	1,102
3,6	Megajoule (MJ)	Kilowatt.hour (kWh)	0,278
0,076	Litre per second (l/s)	Gallon per minute (gal./min.)	13,198
0,028	Cubic metre per second (m3/s)	Cubic foot per second (cfs)	35,315

1 megawatt equals 1 000 kW
1 gigawatt equals 1 000 000 kW

CONCLUSIONS

This study was undertaken to identify and test the feasibility of small hydroelectric plants, or alternative energy sources, in replacing or reducing the use of oil in six communities in the Northwest Territories. The six communities, which are located between 62°N and 68°N Latitude and 68°W and 122°W Longitude, Figure 1.1, are Baker Lake, Coppermine, Fort Simpson - Trout Lake, Frobisher Bay, Rae Lakes and Rankin Inlet, and they presently obtain electricity from diesel generators and heat by the combustion of oil or wood.

Hydroelectricity as an alternative source of energy was found to be potentially viable for only one community, namely, Coppermine. The project at Blody Falls, Coppermine River, may be marginally viable but a full feasibility level and environmental study would be required to confirm its economic viability. For the other communities, the hydro projects were not viable because of a combination of the size of the load, the length of the transmission lines, the lack of enough river flow, lack of head or fall in the river, and the size of the river.

The only other abundant source of energy available locally to produce electricity is wind. Since the present state of wind power technology has yet to provide a cheap method of storing electricity, the intermittent nature of wind necessitates that wind turbines be installed in conjunction with another more reliable power source such as diesel or hydro generators. Therefore, the prime benefit of a wind turbine in conjunction with a diesel generator electrical system is its ability to replace diesel fuel. A preliminary investigation has shown that further studies of a wind-diesel system may be warranted for Baker Lake and Rankin Inlet. However, present indications are that such a system may be marginal and site specific wind data is needed for a period of at least one year at each of these communities.

It must be concluded that, at the present time, the production of electricity by diesel generators is the best option for Fort Simpson-Trout Lake, Forbisher Bay and Rae Lakes. Also, the combustion of oil or wood, as presently occurs for space heating, cannot be replaced by hydroelectricity on a competitive basis. However, where there is a possibility of using natural gas in the future, the cost effectiveness of this energy source for space heating and electrical generation should be investigated.

RAPPORT SOMMAIRE

ÉTUDE D'AMÉNAGEMENTS HYDRO-ÉLECTRIQUES À PETITE ÉCHELLE DANS LES TERRITOIRES DU NORD-OUEST

Résumé

Cette étude a été entreprise afin de déterminer et de démontrer la faisabilité du recours à de petites centrales hydro-électriques ou à d'autres modes de production d'énergie pour remplacer ou réduire la consommation de mazout dans six agglomérations des Territoires du Nord-Ouest. Les six collectivités, situées entre 62 et 68° de latitude nord et 68 et 122° de longitude ouest, sont Baker Lake, Coppermine, Fort Simpson-Trout Lake, Frobisher Bay, Rae Lakes et Rankin Inlet. Toutes tirent leur électricité de génératrices au diesel et se chauffent soit au bois soit au mazout.

Il a été déterminé que l'utilisation de hydro-électricité comme énergie de remplacement est potentiellement viable pour une seule agglomération soit Coppermine. Le projet de Bloody Falls sur la rivière Coppermine serait viable mais une étude complète de faisabilité et d'environnement doit être effectuée afin d'en confirmer la viabilité économique. En ce qui concerne les autres agglomérations, les projets hydro-électriques ne sont pas viables en raison de la charge, de la longueur des lignes de transmission, du faible débit de la rivière, de la faible hauteur de chute et des dimensions de la rivière.

Le vent constitue la seule autre source d'énergie disponible en abondance localement pour la production d'électricité. Étant donné que les spécialistes de l'énergie éolienne n'ont pas encore mis au point une méthode économique visant à constituer des réserves d'électricité, il est nécessaire en raison de la nature irrégulière du vent d'installer des éoliennes joint à des génératrices au diesel ou hydro-électriques, celles-ci constituant une source d'énergie plus fiable. Par conséquent, l'avantage premier qu'offre l'utilisation d'une éolienne joint à une génératrice au diesel c'est qu'il est possible de remplacer le combustible diesel. Un premier examen de la situation a démontré que des études supplémentaires concernant un système éolien peuvent être justifiées à Baker Lake et à Rankin Inlet. Cependant, il semble qu'un tel système pourrait être marginal, des données spécifiques sur le vent doivent donc être recueillies sur une période d'un an au moins à chacune des agglomérations.

En conclusion, à l'heure actuelle la production d'électricité à l'aide de génératrices diesel constitue le meilleur choix pour Fort Simpson-Trout Lake, Frobisher Bay et Rae Lakes. En outre, l'utilisation du mazout ou du bois comme cela se fait présentement pour le chauffage des locaux, ne peut être remplacée de façon concurrentielle par l'hydro-électricité. Toutefois, aux endroits où il sera possible à l'avenir d'utiliser le gaz naturel, un examen de la rentabilité de cette source d'énergie pour le chauffage des locaux et la production d'électricité devra être fait.

Cette étude a été entreprise par Hydrowest Consultants Inc. pour le compte de la Commission d'énergie du Nord canadien avec le concours financier d'Énergie, Mines et Ressources Canada, dans le cadre de son Programme de démonstration dans les collectivités éloignées.

SECTION 1 - INTRODUCTION

1.1 GENERAL

In March 1984, a pre-feasibility study was authorized by the Northern Canada Power Commission (NCPC) to determine the feasibility of construction small hydroelectric generating stations near remote Northwest Territories (NWT) communities. These hydroelectric plants were to replace existing diesel generators and, if possible, oil which is used in furnaces to heat buildings.

Six (6) communities had previously been selected from a list of fourty-one (41) as having reasonable prospects for development, and these communities provided the focus for the pre-feasibility study. The six communities are Baker Lake, Coppermine, Fort Simpson, Frobisher Bay, Rae Lakes and Rankin Inlet, Figure 1.1.

This pre-feasibility study was funded by Energy Mines and Resources Canada under the Remote Community Demonstration Program and awarded to Hydrowest Consultants Inc. During the course of this study, a number of Milestone Reports were prepared and reviewed by the Study Management Committee which consisted of representatives from NCPC, Energy Mines and Resources (EMR), and Department of Indian and Northern Affairs (DIAND). Community liaison during the course of the study was provided by Boreal Ecology of Yellowknife. A list of the reports which were prepared together with their basic contents and date of issue is given below:

Milestone Report #1	Site Screening May 1984
Summary of Milestone Report #1	Site Screening July 1984
Milestone Report #2	Field Investigations and a Deeper Analysis of Baker Lake, Coppermine and Rankin Inlet October 1984
Draft Report Coppermine Development	Final Analysis of the Coppermine Project December 1984
Final Report	Report on work done on all projects February 1985

This particular report summarises, with as little technical language as is needed, the work which was done on the several projects. The reader in need of more elaboration or details should refer to the other volumes mentioned above.

1.2 REMOTE COMMUNITY DEMONSTRATION PROGRAM

Since this study was funded under EMR Canada's Remote Community Demonstration Program, a brief explanation of the programs purpose is given below.

1.2.1 Background

As a result of dramatic increases in the price of oil over the past decade, the Government of Canada saw the need to reduce the nation's dependence on oil. This resulted in a number of national "off-oil energy policies" being established, one of which is the Remote Community Demonstration Program (RCDP).

Approximately 400 remotely located Canadian communities do not have access to electricity grids or natural gas distribution systems. Most of these communities will continue to depend on oil products for electrical power generation and space heating.

The price of oil is high and the transportation of fuel oil to remote areas is costly, difficult and subject to delay and disruption. Where diesel fuel is used to generate electricity, high costs often restrict the use of electricity supply available for homes, community buildings, and local industries.

1.2.2 Purpose

The purpose of the program is to promote the adoption of alternative energy supplies and to encourage energy conservation in remote communities.

The program is aimed specifically at power generation and space heating on the community scale. Its goal is to reduce dependence on oil and broaden awareness of more appropriate (and often locally available) renewable fuels, conservation methods and other practical alternatives.

1.2.3 Phasing

Phase I (October 1982 - September 30, 1984)

In Phase I, the program provided financial assistance for studies to investigate alternative energy supply and energy conservation options available to remote communities. These studies were to help communities to pursue viable options themselves or in conjunction with those agencies responsible for their energy supply. A total of 50 to 60 studies were to be supported in this phase of the program.

Phase II (Summer 1983 - March 31, 1989)

In Phase II, the program will provide financial assistance for demonstrations of practical, effective, and economic energy supply alternatives and energy conservation. Because the costs of such projects are high, relatively few of them will be undertaken. Contributions from the Department of Energy, Mines and Resources are expected to range from $200 000 to $500 000 for each project. Phase II will seek to demonstrate the most practical technologies and measures applicable to remote communities. Information and technology transfer is an essential component of the program; a major factor in selecting demonstrations will be their potential to increase awareness of the demonstrated options in other remote communities. While it is expected that many Phase II proposals will result from Phase I work, Phase I is neither a guarantee of, nor a prerequisite to, Phase II participation.

1.3 SMALL SCALE HYDRO AS AN ALTERNATIVE TO OIL

The ability of small scale hydroelectric power projects to displace oil in remote northern communities, for both the normal electrical load and heating loads, depends upon a number of important factors, namely:

- the size of the electrical load;
- the proximity of a community to a major river which flows during the winter;
- the proximity of a hydro power site with sufficient natural drop in elevation to supply enough power to meet the community's needs;

- the economic viability of hydroelectricity to displace or complement the existing electric and heating systems in the community, as determined by the price of oil and the interest rate to be applied to the capital borrowed to construct the project;
- the acceptability of the hydro project to the local community, electrical utility and the government;
- the environmental impact of the hydro project.

1.4 ENERGY DEMAND

The energy demand for the communities was forecast for both the normal electric load and the heating load, based on population growth and consumption per capita. These requirements are given subsequently in megawatt-hours (1000 kilowatt-hours). The fuel oil consumed for heating has been expressed in equivalent units of electricity; in other words, the amount of energy consumed to heat buildings in the community using oil has been converted to the equivalent amount of electricity required to produce the same amount of heat. Although a number of energy forecasts were made, the one which was adopted for planning purposes, was based upon the following assumptions:

Normal Electric Load

Present electrical use will increase because of population growth and improved lifestyle, but the rate of increase will be dampened somewhat if an allowance is made for conservation.

Heating Load

Present heating requirements will increase because of population growth, but the rate of increase will be reduced if an allowance is made for conservation.

1.5 LOAD SHAPE/DESIGN CAPACITY

The ability of a hydroelectric project to supply enough electricity to satisfy both electric and heating demands will depend upon the amount of flow in the river, the natural drop in the river and the shape of the load.

The load shapes for all of the communities are similar. They show that the normal electric load is relatively stable in comparison to the heating load, which naturally varies considerably with the seasons. The load pattern has the characteristic that the combined heating and electric load requirements in March and April are relatively high at a time when the river flows are low. The reverse is true from June to September when the river flows are high but the load is low.

Because of the daily variations of temperature, the peak heating load, and not the annual amount of energy consumed, is the critical design factor. This peak load tends to occur in January of each year and hence the design capacities of the hydro plants were based on the sum of the peak heating load and the peak of the normal electric load.

The electric load shapes indicate that the power demand in the winter is about two to three times that of the late spring and summer. This is a reverse of the flow pattern of the rivers and hence, on power schemes where there is insufficient minimum flow during the winter, spring and summer flows must be stored for release during the winter periods of highest power demand.

1.6 ALTERNATIVE ENERGY SOURCES

The relevance of alternative energy sources to the NWT depends on the applicability of the particular technology. For the communities, the following were considered.

Heating

Oil, hydroelectricity, wood, gas.

Normal Electric Use

Diesel generators, hydroelectric plants, wind generators.

All other thermo-electric alternatives were rejected on the grounds of:

- size of the load;
- sizes of the generating plant on the market;
- climatic conditions;
- environmental considerations;
- cost of energy from these alternatives.

SECTION 2 - BAKER LAKE

2.1 COMMUNITY SETTING

Baker Lake is an Inuit community of approximately 1000 people. The community is located on the north shore of Baker Lake, near the mouth of the Thelon River.

The economic base in Baker Lake is essentially traditional consisting of hunting, fishing and trapping. Other recently introduced economic activities include arts and crafts and tourism. Baker Lake is also well positioned as a centre from which mineral exploration can take place in the Keewatin District. Rock types found in the Keewatin District have the potential to bear such minerals as uranium, gold, silver, iron, zinc, nickel, copper, cobalt and lead.

Transportation into and out of Baker Lake is limited to air and sea routes. There are no road connections to other centres of habitation.

Full time employment varies between 160 in the winter to 180 during the summer with approximately 85% of those employed being male. At present 34 people are actively looking for work. The potential labour force is estimated at 580 people giving rise to a participation rate of approximately 35%. Per capita income in 1981 was recorded at $4 049 and consumer prices were 60%-70% higher than in Winnipeg.

The lifestyle in Baker Lake may be described as Inuit traditional. There has been a slight change toward increasing wage employment, but social assistance provides a noticeable source of income. Recent wage/contract employment other than government and tourism has been in the mineral exploration sector.

The importance of traditional pursuits is highlighted by the total dominance of caribou (96%) in the Inuit diet of traditional game. To replace the total amount (247 209 kg) of meat/fish with beef at say $10/kg would represent some $2.5 million annually or $11 500 per household. The caribou thus accounts for some $11 000 per household per year in food, and also provides an important source of materials for tents, clothes and artwork.

Quite apart from the economics, caribou hunting is an important way of life to the Inuit. The pursuit of the caribou is a year round activity and plays a crucial part in the community's well-being. The community would be hard pressed to trade-off any significant impacts upon the caribou for economic benefits such as cheaper and more reliable power supply.

2.2 ENERGY DEMAND AND SUPPLY

Electricity is generated in Baker Lake by means of a 2174 kW diesel generating plant. Heat is supplied in the community principally by oil furnaces. The historical and forecasted energy consumption for Baker Lake is presented in Figure 2.1, and the load shape is shown in Figure 2.2. A hydro project near Baker Lake to meet the electric and heating loads at the end of the economic life of the project in 2024, must have an installed capacity of 10 000 kilowatt (10 megawatt).

The energy forecast shows that the amount of energy consumed in Baker Lake for heating is approximately three (3) times the normal electrical use in any given year. Total energy consumption (electric + heating) could more than double over the next 40 years even after taking conservation measures into account. It should also be pointed out that energy savings due to conservation in heating could almost equal as much as the normal electric requirement (e.g., the heating energy saving through conservation by 2024 could amount to 6800 megawatt-hours in Baker Lake. This is almost eaual to the low electrical forecast of 7704 megawatt-hours in 2024).

2.3 POTENTIAL SITES

There are a number of potential sites for hydro power development in the vicinity of Baker Lake. These include the Kazan Falls, the Quoich River at St. Clair Falls, Kingyouuq Creek, Prince River, and the Thelon River.

Both the Kazan Falls and Quoich River sites were ruled out from further investigation due to their distance from Baker Lake (80-90 km). For small hydroelectric plants, a 25 km transmission distance is about the acceptable maximum distance from the load centre. The Prince River site was not investigated further due to the technical problems and costs associated with the construction of a 6,4 km penstock. A scheme on the Kingyouuq Creek - the Lake Scheme - was identified and examined in the first phase of the study, but it was rejected because of its complexity and inferior economics. This left the Thelon River as the best site for detailed investigation.

2.4 PROJECT DESCRIPTION (THELON RIVER

The Thelon River site is shown on Figure 2.3 in the vicinity of Tupik Lake which is located 12 km upstream from Baker Lake.

Since the natural fall in the Thelon river at the site of the project is small, a 10 metre high rockfill dam would have to be constructed 300 metres across the river. With this artificial fall caused by the dam, and the large natural flow in the river, it is possible to obtain the required 10 megawatt plant. A fishlock and boat slide would also have to be built to pass fish and boats across the dam. A powerhouse would be located underground in the rock on the left bank of the river to protect it from ice damage. A 450 metre diversion tunnel and six cofferdams would be required during construction to divert the river at low flow periods and allow construction of the dam. The conceptial design layout is illustrated by Figures 2.4 and 2.5. The flow in the Thelon river is shown in Figure 2.6. The capital cost to build the project is estimated at $70 million (excluding costs for feasibility and environmental studies).

2.5 ENVIRONMENTAL IMPACT

Environmental concerns surrounding the building of a dam across the Thelon near Tupik Lake relate to:

- caribou
- fisheries
- ice
- Heritage rivers

2.5.1 Caribou

Unquestionably, caribou is the most important wildlife species to residents of Baker Lake. There are three herds of caribou which pass near the community, namely, Kaminuriak, Beverly, and Wager Bay. The caribou harvest for 1982/83 by Baker Lake residents was estimated at 5000. This accounts for approximately 96% of the total harvest by edible weight.

Concerns with respect to the caribou surround two issues, namely:

1) transportation up the Thelon River to hunt caribou and hence the impact of the dam seem as an obstacle;

2) the impact on caribou migration as a result of constructing such a project.

2.5.2 Fisheries

Fish species inhabiting Baker Lake and the Thelon River between Baker and Schultz Lakes include arctic char, arctic grayling, lake trout and round whitefish. The use made of the Thelon River by the Baker Lake fish population is unknown.

Concerns are two fold with respect to the effect on fisheries, namely:

1) blocking of fish migrations;

2) creation of a "lake habitat" above the dam for a distance of some 10 km.

2.5.3 Ice

Considerable concern was expressed by local residents with respect to the impact of a dam on ice movements and vice versa. During ice breakup on the Thelon river, ice jams can cause ice build-up which scour the river bottom and banks. An obstruction across the river could impede the movement of ice downstream. The dam would have to be designed to withstand the forces associated with ice build-up and ice movements across it.

2.5.4 Heritage River

The Thelon River has been given a high priority by Parks Canada under the Heritage River Program. However, the provision of a boat slide and portage route should adequately provide for movement across the dam. The impact on the natural characteristics of the river would be limited to raising the elevation of the river 10 m behind the dam, reducing to zero at a point about 10 km upstream of the dam.

2.6 ECONOMIC EVALUATION

The cost to build a 10 megawatt hydroelectric project on the Thelon River is estimated at about $70 million (1984 dollars) as shown in Table 2.1. This high cost is largely due to the size of the Thelon River and the lack of natural head at the Tupik Lake site. The diversion tunnel alone accounts for 20% of the cost of the project and the main dam and cofferdams account for 15% of the cost.

TABLE 2.1

BAKER LAKE DEVELOPMENT

COST ESTIMATES (1984 dollars)

Item	Costs (millions of dollars) 10.4 MW	
Civil Works		
Access	1.500	
Cofferdams	3.760	
Main dam	6.590	
Fish lock	1.197	
Boat lift	0.150	
Diversion tunnel	14.650	
Power tunnel	1.230	
Penstock	0.788	
Powerhouse	3.672	
Tailrace	1.760	
Sub-total		35.297
Electrical and Mechanical		
Turbines	3.908	
Generators	2.306	
Miscellaneous equipment		
Electrical	1.325	
Mechanical	1.652	
Intake Equipment	1.183	
Outlet equipment	1.582	
Transmission line	1.095	
Sub-total		13.051
Indirect costs		4.765
Engineering and management (10%)		5.311
Contingencies (10%)		5.842
Construction cost		64.266
Interest during construction		5.353
Capital cost		69.619
Cost/kW	$6 694	

Note: 1) Estimated capital costs are ± 20% in accuracy.
2) Does not include costs for feasibility and environmental studies.

The construction cost of the hydro project together with the operating/maintenance costs result in the cost of energy, for the amount of energy actually used, being 21,1 ¢/kWh at a discount rate of 6% p.a.. The comparative combined cost of energy from the existing diesel system and home heating oil is valued at 11,6 ¢/kWh.

The present cost of producing electricity from diesel generators in Baker Lake in 1984 was estimated at 24.5 ¢/kWh. Comparable rates for domestic consumption (non-government) were 22.6 ¢/kWh for the first 300 kWh per month in 1985. A conservative estimate of the cost to build a dam across the Thelon River to supply only the electrical load of 2.0 MW is $[illegible], resulting in a delivered electrical cost to the community of 36 ¢/kWh. Therefore, a hydro scheme built on the Thelon River to serve the needs of Baker Lake would provide energy at a cost which is more than that of the present system. The hydro scheme is therefore not economically viable.

2.7 ALTERNATIVE ENERGY SOURCES

Since hydroelectric power is uneconomic without additional loads other sources of energy were explored. Historical photographs reveal that some homes were powered by individual wind mills prior to the introduction of diesel generators.

From initial investigations the energy source with the greatest potential in Baker Lake appears to be wind. A preliminary examination has shown that the cost of energy from the wind for producing electricity only at a discount rate of 6% p.a., and not for heating, is 16.0 ¢/kWh compared to the cost of electricity from the diesel generators of 25,6 ¢/kWh. However, this evaluation is based on wind data which is not site specific, and it would be necessary to collect wind data near the community at a specific location.

It is therefore suggested that these should be further studies with respect to the feasibility of a wind farm/diesel hybrid system for Baker Lake in an effort to displace some diesel generated electricity. Another possibility might be the use of wind energy to pump water to an elevated lake with sufficient storage capacity and then dropping it through a penstock to generate hydro-electricity.

2.8 CONCLUSIONS

1) A small scale hydro project across the Thelon River at Tupik Lake is capable of meeting local demand for electricity and heat. However, without additional load to offset the high costs and unused energy produced, the project is uneconomic.

2) A wind/diesel hybrid system should be studied further to determine its feasibility for displacing diesel oil in Baker Lake. However, site specific wind data must be collected for at least one year.

3) Base line environmental data is lacking for both the caribou and fish. Such information will be required for any future hydro studies.

SECTION 3 - COPPERMINE

3.1 COMMUNITY SETTING

Coppermine is an Inuit community of 890 people, and it is located on the Arctic coast of the mouth of the Coppermine River and Coronation Gulf. The community takes its name from the Hudson's Bay Company which sent explorers from Fort Prince of Wales to find the source of native copper brought to the fort - hence the name "Copper Inuit".

The economic base of Coppermine is largely traditional, although some members of the community have become involved with offshore exploration for oil and gas in the Beaufort Sea. Artic char, seals and caribou are harvested along with polar bear, musk-ox and small game. Tourism depends mostly upon the sale of arts and crafts, char fishing and the fact that Coppermine is the terminus of canoeing expeditions on the Coppermine River. Mineral potential of the area consists of gold, uranium, iron, zinc, lead, silver, cobalt, nickel and, of course, copper.

A rough estimate of present employment is given below:

Government (GNWT/Hamlet)	38
Oil and Gas	32
Mining	12
Retail	18
Utilities	2
Transportation	2
Service	6
Construction	14
Hunters/Trappers/Fishermen	
- Full time	5
- Part time (seasonal)	60
Total	189

With an estimated labour force of 530 people, the participation rate is roughly 36%. Per capita income in 1981 was recorded at $4 400 and consumer prices were 70%-80% higher than those in Edmonton (1983).

The lifestyle in the community may be described as Inuit traditional with a gradual change toward increasing wage employment and social assistance. Recent wage employment other than government has been provided by the non-renewable resource sectors of oil and gas and mining.

The importance of traditional pursuits in the community is highlighted in Table A - 2.1, below. These figures must be considered conservative since they are only based on approximately 11 months of data, and with only 50% of the hunters reporting.

TABLE A - 2.1

Estimated Coppermine Harvest (1983)

Species	No.	Estimated Avg. Edible Weight (kg)/Species	Total Est. Edible Weight Available Each Year (kg)	%
Caribou	1 270	48	60 960	54
Seals	549	14	7 690	7
Char	8 531	2,5	21 330	19
Whitefish	5 188	2,8	14 530	13
Trout	1 756	2,4	4 210	4
Musk-Ox	18	110	1 980	2
Moose	7	199	1 390	1
Wolves	49	-	-	-
Wolverine	64	-	-	-
Arctic Hares	89	2,3	200	-
Ptarmigan	477	0,4	190	-
Ducks	562	0,7	390	-
Geese	191	2,4	460	-
		Total	113 330	100

Source: GNWT - Renewable Resources

Note: Reporting rate - 50%

To replace the total amount (113 300 kg) of meat/fish with say beef at $10/kg would represent 1.1 million dollars annually or $5 600 per household. In percentage terms, this shows that the migrating fish of char and whitefish account for about one-third of the total diet. The domestic fishery could therefore represent one-third or $1 900/household.

Quite apart from the economics, fishing is an important way of life to the Inuit. The domestic fishery provides the occasion to move the family out of the community to summer residences located between the estuary and Bloody Falls; residences consist of both wood cabins and tents. Transportation between these summer residences and the community is by means of boat fitted with on outboard engine.

Trapping is one of the traditional ways of life of the Inuit at Coppermine, and the value of fur harvested for the year 1982/83 was estimated at $67 700.

3.2 ENERGY DEMAND AND SUPPLY

Electricity is generated in Coppermine by a 1575 kW diesel plant. Heat is principally supplied by oil furnaces. In 1983/84 electrical generation amounted to 2655 Megawatt-hours with a peak load of 620 kW, while 329 200 gallons of heating oil (equivalent to 9500 Megawatt-hours of energy) were consumed by oil furnaces. The existing heating load is roughly three and one half (3½) times the electric load in Coppermine. The historical and forecasted energy demand for Coppermine is presented in Figure 3.1, and the load shape is shown in Figure 3.2.

The capacity of a hydro project near Coppermine which could meet both the electric and heating loads to the end of the economic life of the project in 2024, would have to be 10 Megawatt. To supply the electric load only, a plant having at least a 1,8 Megawatt capacity would be needed.

This energy forecast shows that the amount of energy consumed in Coppermine for heating is approximately three-and-one-half (3½) times the normal electrical use in any given year. Total energy consumption (electric + heating) could triple over the next 40 years even after taking conservation measures into account. It should also be pointed out that energy savings due to conservation in heating could total as much as the total normal electric requirement (e.g., the annual energy saving in heating through conservation by 2024 could amount to 6600 MWh in Coppermine. This is greater than the low electrical forecast of 5649 MWh in 2024).

3.3 POTENTIAL SITES

Three possible hydroelectric sites were investigated with regard to their suitability to meet the energy demand of Coppermine. They were:

- Kendall River near Dismal Lakes
- Escape Rapids, Coppermine River
- Bloody Falls, Coppermine River

The first two sites were ruled out because of their long distance from Coppermine and small natural elevation drop. Also, in the case of the Kendall River it freezes to the bottom during winter.

The Bloody Falls site, Figure 3.3, was examined initially with the objective of satisfying both the electrical and heating loads in Coppermine. Development of Bloody Falls to achieve this objective involved the construction of a 15 metre high overflow rockfill dam just upstream of the falls, a diversion/power tunnel, fish ladder and powerhouse. It became evident during the course of the study that this particular development of the site was marginally economic. It also presented difficult environmental problems which would have to be overcome with respect to migrating arctic char.

The inefficiency of attempting to harness a site on a large river having substantial power potential to serve a small and highly variable load was clearly demonstrated. It was decided to investigate an alternative scheme which would not require a dam and which would utilize the natural flow and elevation drop in the river. The prime objective became that of meeting only the electric load and any surplus energy was to be considered useable for electric heating.

3.4 PROJECT DESCRIPTION

The proposed Coppermine hydro project would consist of an interception trough constructed just upstream of Bloody Falls in the bed of the river, water intake together with a 5 m diameter tunnel, semi-underground powerhouse, access road, portage, and 12 kV transmission line from Bloody Falls to Coppermine.

It is estimated that this project would spill about 40% of the average monthly flow during March and April of each year down the falls. During July, 98% of the average river flow would pass down the falls. The average flows in the Coppermine river at Bloody Falls are shown in Figure 3.4.

The conceptual layout for the project is shown in Figures 3.5 and 3.6. A tentative construction schedule is shown in Figure 3.7. The project would be constructed over a three year period with major river work scheduled for periods of low flow and ice cover.

3.5 ENVIRONMENTAL IMPACT

Environmental concerns surrounding the proposed hydro project at Bloody Falls can be identified under:

- Fisheries
- Canal portage
- Aesthetics

3.5.1 Fisheries

The maintenance of the population of arctic char and other species in the Coppermine river depends on unobstructed passage upstream and downstream through Bloody Falls. Prevention of this passage would seriously jeopardize these populations and cause severe hardships for the community. However, the present design of the project does not interfere with movement of fish in the river. There is need, however, to ensure that the fish do not enter the intake or swim up the tailrace tunnel. This can be achieved by the use of screens as has been done for other projects.

The rated turbine flows are less than the anticipated minimum flow in the river during March/April, for all but one scheme, but there will be a substantial flow depletion from the normal river channel. It is therefore necessary to confirm the migratory periods of char and other species in the river to determine acceptable construction procedures and minimum flows over the falls which will need to be maintained during migratory periods.

To provide baseline information on the fish population for use in designing the project, a detailed field program is required. The basis of the program would be counting fences operated in two consecutive years. Fish ascending and descending the rapids would be enumerated by species and size and tagged and samples would be taken for more detailed analysis (age, length, weight, sexual development).

Based on a field program lasting two years, making considerable use of local assistance, the costs of the required fisheries studies, including laboratory work and reporting, are likely to be in the order of $300 000.

3.5.2 Canoe Portage

As far as access around the falls is concerned, the construction of a road from the bottom of the falls to the intake will be of benefit to canoe trippers. This is therefore an improvement on the present situation.

3.5.3 Aesthetics

The hydro scheme is designed as a run-of-the river development which will include the construction of a diversion water conveyance system. Due to the flow characteristics of the river and the pattern of the forecasted load, over 98% of the flow during the summer will be spilled, thereby not visibly altering the downstream aesthetics of the present rapids. During the winter the flow in the rapids will be reduced to about 40% the normal discharge due to the hydro development.

The top of the powerhouse which is located downstream of two perched lakes will be not much above the existing ground level. The completed powerhouse thus presents a minimum of interference with the surroundings.

3.6 ECONOMIC EVALUATION

The cost to build a 1,9 Megawatt power plant at Coppermine is estimated at $17.89 million as shown in Table 3.1. To this should be added $1 million for environmental and feasibility studies. This cost estimate includes all aspects of the project such as the intake, tunnel, powerhouse, equipment, access road, transmission line and interest during construction.

An economic comparison of alternative electrical supply systems for Coppermine was made as follows:

System 1 (Status Quo) - All diesel
System 2 - Combination (Hydro + diesel)

Should the present diesel system be retained as the only source of electricity, then the existing units will be replaced at the end of their economic life (20 years) with units which provide additional capacity to cater for future growth.

TABLE 3.1

COPPERMINE DEVELOPMENT

COST ESTIMATES (1984 dollars)

1888 kW

Item	Costs (millions of dollars)	
Civil Works		
Access	0.605	
Cofferdams	0.390	
Intercepting trough	0.270	
Intake	0.806	
Tunnel and surge shaft	4.038	
Canal	0.053	
Powerhouse	2.219	
Tailrace	0.086	
Sub-total		8.467
Electrical and Mechanical		
Turbine	0.900	
Generator	0.515	
Miscellaneous equipment		
Electrical	0.333	
Mechanical	0.361	
Intake Equipment	0.406	
Outlet equipment	0.180	
Transmission line	0.860	
Sub-total		3.555
Indirect construction costs (15% of civil works)		1.270
Engineering and management (10%)		1.329
Sub-total		14.621
Contingencies (10%)		1.462
Construction cost		16.083
Interest during construction (8%)		1.804
Capital cost		17.887
Cost/kW	$9 474	

Note: 1) Estimated capital costs are ± 20% in accuracy
2) Does not include costs for feasibility and environmental studies.

Under the hydro-diesel alternative, the system will start generating electricity by 1992 and surplus electricity will be sold for electric heating. Some 245 households (or an equivalent commercial/institutional load) would have to be converted to use electricity for heating. In the analysis which was made, the price of electric heat was taken as 90% of the price of oil heat (56 ¢/litre), and the cost of converting a house from oil to electric heat was assumed to be $2 200.

With the hydro-diesel combination, 2200 kW of diesel power would still be maintained in the system after the hydro is brought on line in 1992. However, the diesel units would be maintained on a standby capacity only. By having this reserve amount of diesel power, the diesel units can take over in the event of a shut down at the hydro plant, due to routine maintenance or an unexpected power interruption.

An analysis of the comparative economics of an all diesel system and a combined hydro/diesel system was performed. The analysis included as well as excluded a heat credit for the sale of surplus power and the results are summarized below for a discount rate of 8% p.a.:

Alternative	Average Generation Cost (cents/kWh)	Pay Back Period (years)	Benefit/Cost Ratio
All diesel	37.8	NA	
Hydro + Diesel			
. heating sales included	33.6	20	1.17
. heating sales excluded	41.2	40	

The cost of the hydro energy in the hydro-diesel system was:

- heating sales 31.7 ¢/kWh
- no heating sales 43.4 ¢/kWh

The results of this analysis show that if the surplus electricity is not used for heating purposes then the cost of energy from the hydro-diesel system is more expensive than the cost of energy from the diesel system. The importance of using the surplus energy is therefore clear, but the hydro-diesel system, once operational, would insulate the community's supply of electricity from increases in the price of diesel oil. With a capital costs increase of 20%, which is the order of error of the estimate, Benefit/Cost ratio would reduce to 0.93.

3.7 ALTERNATIVE ENERGY SOURCES

The only practical alternative energy for Coppermine is wind energy. A brief examination of this alternative was made using as average wind speed of 16,4 km/h. It was found that the cost of wind energy would be 43.4 ¢/kWh at 8% discount rate. This cost is greater than the cost of energy from the diesel system and is therefore not an economic alternative.

3.8 CONCLUSIONS

1) A small scale hydroelectric project of 1,9 MW capacity is estimated to cost $18.89 million, constructed at Bloody Falls. The project appears to be economically viable at a discount rate of 8% if surplus energy can be sold for heating, for the best estimate of capital costs, but not viable if capital costs increase by 20%. It is evidently not viable if there are no heat sales.

2) The project has been designed in a manner to minimize the effect upon the environment. This is due to the fact that no dam is required, and that the aesthetics of the falls are for the most part maintained.

3) Environmental studies (including fish migration studies) would be required to better determine acceptable construction and operating criteria for the hydro-diesel system, if the project were to proceed.

4) The project would require approximately 34 months to construct and the optimum commissioning date is estimated to be 1992.For this to occur the possible development schedule is as follows:

Environmental Study	1985/86
Feasibility Study	1985/86
Design/Tender	1987/88
Construction	1989-1991
1st Year of Hydro Power	1992

SECTION 4 - FORT SIMPSON-TROUT LAKE

4.1 COMMUNITY SETTING

Fort Simpson is located at the confluence of the Liard and Mackenzie Rivers as well as at the junction of the Liard and Mackenzie Highways. These highways link the community to Vancouver and Edmonton, respectively.

Fort Simpson was established as a trading post about 1804 by the Northwest Company and is now an administrative centre for the territorial government. It is a transportation centre possessing important air, road, and water links to the west of Canada and is thus strategically located to provide an important logistics centre for the exploration of oil, gas and minerals in the surrounding area. The community is also situated at the northern edge of the Boreal Forest and significant stands of timber are located along the Liard river valley.

The present population is estimated at 1010 of which about half are Dene. The natural growth rate is estimated at 1,9% p.a. Even though the community is relatively small, the economic base and resource potential in the area is diverse. Major economic activities include government, transportation, hunting, trapping, forestry, and tourism. Resource potential in the region includes oil, gas, minerals and agricultural land.

The hydroelectric project is also intended to serve the small community on the south-eastern shore of Trout Lake. The community of about 60 persons has an airstrip but is presently not supplied with electricity.

4.2 ENERGY DEMAND AND SUPPLY

The community presently receives electricity from diesel generators which have a total capacity of 5535 kW. The electrical load in 1982/83 amounted to 5768 MWh with a load factor of 66%. Annual growth over the past few years showed a decrease of 0,8% reflecting the loss in population over the period.

Space heating is supplied by oil furnaces and wood. In 1978/79, 838 829 gallons of heating oil were consumed. This is equivalent to approximately 24 210 MWh of heat as an electrical load and it is roughly 4,1 times the normal electrical load. For the purpose of estimating the possible space heating electrical load, it was assumed that 20% of the heat will be supplied by wood or propane.

Both the historical and forecasted energy consumption for Fort Simpson-Trout Lake is presented in Figure 4.1. Total energy consumption (electric + heating) which presently is linked to oil in Fort Simpson could triple over the next 40 years. It should be noted that the major increase in electrical consumption between 1981 and 1994 is a result of providing 1 Megawatt of power to either an oil pumping station or a gas compressor station on a major oil or gas transmission pipeline.

The capacity of a hydro project near Fort Simpson to meet both the electric and heating loads in 1994 would have to be 16 Megawatt. This high capacity is caused by the heating load and the shape of the load which is shown in Figure 4.2. To supply the electric load only, a plant of 3,7 Megawatts would be needed.

4.3 POTENTIAL SITES

Previous studies have recommended harnessing the potential power of Whittaker Falls (14,3 m) and Coral Falls (5,2 m) on the Trout River to supply the energy needs of Fort Simpson. This site is about 120 km east of Fort Simpson, Figure 4.3, but it appears to be the best site for a small scale hydro development. The advantages are that the river does not freeze to the bottom during the winter, and Trout Lake in the upstream catchment can be used to regulate the river flows.

4.4 PROJECT DESCRIPTION

The maximum power which could be obtained from the Whittaker-Coral Falls is about 4,8 MW using only flow regulated by Trout Lake. Figure 4.3 shows the flow which is available in the Trout river system. This power output is insufficient to justify such a long transmission line (120 km) from the Whittaker Falls power plant to Fort Simpson. Another site upstream of these falls was therefore sought so that the regulated flow could be used more than once.

Figure 4.4 shows the upstream site which was located, and the layout of the development. There would be a low dam and control structure at the exit of Trout Lake. At the upstream site the diverted flows would be taken by a canal along the 396 m (1300 ft) contour and then a pipe to a powerhouse about 30 m below the general elevation of the canal. The powerhouse of 8,5 MW would be on the right bank of the river and a 68 km transmission line would link it with the Trout Lake community. There would also be a transmission link beteeen the upstream and downstream

powerhouses. Downstream at the Whittaker Falls site, there would be a low dam and intake, similar to the upstream site, and the diverted flow would be taken to a powerhouse on the left bank of the river by a tunnel and/or pipe. The capacity of this powerhouse would be 5,5 MW.

Because Trout Lake is about 500 km2, the height of storage which would be required to conserve the spring and summer runoff is only 0,73 m. Important aspects of this scheme are:

- the lake level would be raised 0,73 m;
- the river level at the upstream site would be raised about 2,0 m;
- the river level south of the highway would be raised 3,0 m;
- there would be no spring and summer releases from Trout lake;
- the river level during the winter would be much higher than normal.

The capital cost of the total scheme is estimated at $59 million.

4.5 ENVIRONMENTAL IMPACT

The environmental impact of the Trout River scheme was investigated in a preliminary manner. Since the project was not economically viable, no detailed surveys were conducted.However, preliminary analysis would suggest the following environmental concerns with the project:

- potential flooding of a portion of the Trout Lake community as a result of water storage in Trout Lake;
- possible impedence to fish by dams on the Trout River;
- road access provided to Trout Lake from Highway #1.

4.6 ECONOMIC EVALUATION

The cost to build a 14 Megawatt project to serve the electric and heating loads in Fort Simpson-Trout Lake would amount to approximately $59 million. Table 4.1 shows the detailed cost. This project is very expensive largely due to the cost of building a 120 km transmission line which accounts for about 30% of the capital cost of the project.

TABLE 4.1

PROJECT COST (1984 dollars)

FORT SIMPSON/TROUT LAKE

		Millions of $	Millions of $
1.	Camp facilities	1.577	
2.	Dams and diversion	1.566	
3.	Lake control structure	1.390	
4.	Water conveyance system	8.072	
5.	Powerhouse	0.750	
6.	Access	1.365	
7.	Transportation	0.789	
8.	Sub-total of Civil Works (C.W.)		15.509
9.	Electrical and Mechanical		
	- Equipment	4.481	
	- Services	2.205	
	- Erection	1.176	
10.	Transmission	15.743	
11.	Sub-total of E&M		23.605
12.	Contingencies		
	- Civil (20%)	3.102	
	- E&M (8%)	1.888	
13.	Engineering (10%)	4.410	
14.	Sub-total of Direct Cost	48.514	
15.	Indirect Costs (45% of C.W.)	6.979	
16.	Capital Cost	55.493	
17.	Interest during construction (6%)	3.330	
18.	Construction Cost	58.823	
19.	Unit Cost	$4 202/kW	

Notes: 1) Estimated capital costs are ± 20% in accuracy
2) Does not include costs for feasibility and environmental studies.

The effective cost of energy, i.e., the cost of energy calculated on the actual amount of energy sold, from such a power scheme would amount to 8,7 ¢/kWh at a discount rate of 6% p.a.. This cost does not compare well to an equivalent cost of 7,9 ¢/kWh for diesel generated electricity and oil-produced heat. Therefore, the project is not economically viable.

The project is also incapable of displacing diesel oil used to generate electricity. The cost of diesel oil is equivalent to 11,7 ¢/kWh, while the transmission line costs alone of the hydro project would be equivalent to 9 ¢/kWh, with no allowance for the cost of developing the power sites on the Trout River and control structure on the outlet to Trout Lake.

4.7 ALTERNATIVE ENERGY SOURCES

Other potential energy sources which the community may wish to investigate include wood, natural gas and wind.

4.7.1 Wood

Wood presently supplies Fort Simpson with 10% of its heating demand. This source of fuel will likely continue to be used in the community but environmental considerations may ultimately limit its use. These considerations relate to both the harvesting of the wood and the resulting air pollution from burning which can be aggravated by inversion conditions.

4.7.2 Natural Gas

Natural gas from either local gas fields or via a lateral pipeline from a Mackenzie Valley Gas Pipeline has a good chance of being economically viable in the future. This could supply the heating demands in Fort Simpson and possibly Trout Lake.

4.7.3 Wind

The wind regime in the Fort Simpson area is too low to allow the consideration of wind generators.

4.8 CONCLUSIONS

1) Small scale hydro potential exists on the Trout River and a plant capacity of 14 Megawatts can be realised.

2) A hydro project to meet the energy demand of Fort Simpson and Trout Lake is uneconomic due to the long transmission distance (120 + 68) km between the power sites and the load centres.

3) Space heating might be better serviced by alternative energy sources such as natural gas and wood.

SECTION 5 - FROBISHER BAY

5.1 COMMUNITY SETTING

Frobisher Bay has its roots in the establishment of a trading post at Ward Inlet, near the present townsite by the Hudson's Bay Company. The community is located on Koojesse Inlet near the northeast head of Frobisher Bay, Baffin Island. The U.S. Air Force constructed a major air base during the 2nd World War and followed this up with the construction of the Distant Early Warning (DEW) line in the 1950's. Future plans call for the establishment of a new capital city at Frobisher for the Eastern Arctic. Transportation is limited to air and sea routes.

The present population is estimated at 2630 of which two-thirds are Inuit.

The economic base of Frobisher Bay consists of government, transportation, communications, fishing, sealing, trapping and tourism. Fish harvesting includes arctic char and mammal harvesting includes whales, walrus, and seals. Polar bears are also hunted on the quota system.

5.2 ENERGY DEMAND AND SUPPLY

The community presently receives electricity from diesel generators which have a total capacity of 9945 kW. The electrical load in 1982/83 amounted to 20 971 MWh with a load factor of 61%. Annual growth over the past 6 years averaged 1,6%.

Space heating is supplied by oil furnaces and district heating using boiler heat from the NCPC facilities. In 1978/79, 1 109 037 gallons of heating oil were consumed. This is equivalent to approximately 32 000 MWh of heat as an electrical load and it is roughly 1,8 times the normal electrical load.

Both the historical and forecasted energy consumption for Frobisher Bay is presented in Figure 5.1 and the shape of the load is shown in Figure 5.2. Total energy consumption could more than triple over the next 40 years.

To meet the electric load only in 2024 an 11,0 Megawatt hydro installation would be required.

5.3 PROJECT DESCRIPTION

The proposed development was first investigated in 1975, and is located on the Sylvia Grinnell river. It was proposed to construct a rockfill, overflow dam and control structure at the outlet of the Sylvia Grinnell lake to allow the spring and summer flows to the lake to be stored for winter releases. There are no significant water falls in the river and hence a dam must be built to create head for a downstream power plant. The least cost energy could be obtained by constructing a rockfill dam 56 m high about 10 km from Frobisher Bay. Appurtenant structures would be a spillway and a powerhouse, both on the left bank of the river. Figure 5.3 gives the general layout of the scheme. The power plant has a capacity of 7,5 MW, utilises a flow of 18,6 m^3/s and would cost $94 million. The flow in the Sylvia Grinnell river is shown in figure 5.4.

5.4 ENVIRONMENTAL IMPACT

Although the Sylvia Grinnell River is not used for navigation by local hunters in summer, there is local concern that winter flows will make the river crossing hazardous. Almost all winter hunting by residents of the community involves travel up the river. Varying water levels in winter could create both hazardous and treacherous conditions involving overflow and or weak ice.

With respect to fisheries, the Sylvia Grinnell was one of the earliest commercial char fisheries in the N.W.T.. Overexploitation reduced the fishery drastically and almost wiped the stock out. Whereas formerly this river produced 10 000 lbs. for commercial sale annually, the harvest is now restricted to domestic and recreational fishing. Recent efforts by Fisheries and Oceans, involving extensive discussion with the local Hunters' and Trappers' Association, have focussed on restoring the stock. Both parties will resist any schemes that may thwart the recovery of this fish stock.

5.5 ECONOMIC EVALUATION

The cost to build a 7,5 Megawatt plant to supply the electric energy demand in Frobisher Bay for about 40 years would amount to approximately $94 million, as shown in Table 5.1. The effective cost of energy produced would amount 20,6 ¢/kWh. This compares with an equivalent cost of 19,5 ¢/kWh for diesel generated electricity. Therefore, the project is not economically viable.

TABLE 5.1

PROJECT COST (1984 dollars)

SYLVIA GRINNELL

		Millions of $	Millions of $
1.	Camp facilities	4.258	
2.	Dams and diversion - Lake	1.894	
	- Main dam	18.628	
3.	Spillway	5.528	
4.	Water conveyance system - Lake	3.188	
	- Main dam	0.702	
5.	Powerhouse.	1.008	
6.	Access	4.535	
7.	Transportation	2.129	
8.	Sub-total of Civil Works (C.W.)		41.870
9.	Electrical and Mechanical		
	- Equipment	8.180	
	- Services	1.156	
	- Erection	0.900	
10.	Transmission	0.630	
11.	Sub-total of E&M		10.866
12.	Contingencies		
	- Civil (20%)	8.374	
	- E&M (8%)	0.869	
13.	Engineering (10%)	6.198	
14.	Sub-total of Direct Cost	68.177	
15.	Indirect Costs (45% of C.W.)	18.842	
16.	Capital Cost	87.019	
17.	Interest during construction (8%)*	6.962	
18.	Construction Cost	93.981	
19.	Unit Cost	$12 531/kW	

* Longer construction period.

Notes: 1) Estimated capital costs are ± 20% in accuracy
2) Does not include costs for feasibility and environmental studies.

5.6 ALTERNATIVE ENERGY SOURCE

The use of wind as an alternative energy source was investigated, and it was estimated that wind energy could be produced at 50,2 ¢/kWh at 6% p.a. discount rate. It must be concluded that this is not an alternative option which should be pursued any further.

5.7 CONCLUSIONS

1) Small hydro is not an economically viable electrical energy source for Frobisher Bay, because of the relatively small rivers on Baffin Island compared with those on the mainland.

2) Even if the project was viable, there would be serious concerns with respect to the environmental acceptability of the development due to the state of the char fishery on the Sylvia Grinnell.

SECTION 6 - RAE LAKES

6.1 COMMUNITY SETTING

Rae Lakes is located on Rae Lake, 177 km northwest of Yellowknife. Rae Lake is a part of an interior chain of lakes between Great Bear and Great Slave Lakes. The lakes lie at the boundary between the Canadian Shield and the Interior Plains in the transition forest region. Traditionally, the area has been the hunting ground of the Dogrib Dene from the Rae area. This previous hunting outpost has become a permanent community with the construction of community buildings and infrastructure in the 1970's.

Rae Lakes is a Dene community of 210 people with a natural growth rate of about 1,7% p.a.

The economic base of Rae Lakes is the traditional persuits of fishing, hunting and trapping. Annual harvests consist of lake trout, whitefish, caribou and small fur bearing animals. There is relatively high mineral potential in the area, and this includes uranium. Transportation into the community is principally by air with a winter road joining the community to the Mackenzie Highway at Rae-Edzo.

6.2 ENERGY DEMAND AND SUPPLY

The community presently receives electricity from diesel generators which have a total capacity of 260 kW. The electrical load in 1982/83 amounted to 178 MWh with a load factor of 45%. Annual growth over the past 6 years averaged 2,8%.

Space heating in Rae Lakes is presently supplied almost exclusively by wood consisting of jack pine and some spruce. The community consumes approximately 400 cords annually with an average consumption of approximately 12 cords per household. The present electrical equivalent of the space heating market in Rae Lakes has been estimated at 1200 MWh, assuming that 20% of the load will always be supplied by other fuels (eg., wood, propane). On the basis of sales this heating load is roughly 6,7 times the electrical load.

Both the historic and forecasted energy consumption for Rae Lakes is presented in Figure 6.1 and the load shape is shown in Figure 6.2. As the former figure shows, the total energy consumption could more than double over the next 40 years.

To meet the energy requirements of the combined electric and heating loads in Rae Lakes to year 2024, a 1200 kilowatt plant would be required. To supply the electrical load only a 100 kilowatt plant would be sufficient.

6.3 PROJECT DESCRIPTION

Two possible developments were examined for Rae Lakes. The first uses the fall between Rae Lake and Lac Ste-Croix, and the second uses the fall between Rae Lake and Taka Lake, Figures 6.3 and 6.4. Both schemes require the storage of water in Faber Lake and its controlled release during the winter. The flow in the Camsell river at Rae Lakes is shown in Figure 6.5.

The Rae Lake/Lac Ste-Croix scheme would require a dam and intake between the two lake systems and the powerhouse at Lac Ste-Croix. The installed capacity in the powerhouse is 250 kW. The Taka diversion scheme would require a dam and intake on Rae Lake, as well as a dam at the Rae Lake/Lac Ste-Croix junction to prevent the escape of water into Lac Ste-Croix. The powerhouse for the Taka diversion scheme would be on Taka Lake, and would have an installed capacity of 500 kW.

Water would be conveyed to the powerhouses in insulated pipes. The conveyance system for the Taka diversion would also require the excavation of a channel and would thus be more costly.

A third possibility was considered, that of putting a larger dam at Faber Lake, and a powerhouse on the Rae Lake side of the junction of Faber Lake and Rae Lake. The cost of such a scheme was found to be more than the two schemes discussed above and was therefore discarded.

The water levels in Faber Lake would be raised 4,2 m while that in Rae Lakes would be raised 0,7 m.

Each scheme requires a transmission line of about 25 km.

6.4 ECONOMIC EVALUATION

The Rae Lake-Lac Ste Croix scheme costs $4,4 million while the Rae Lake-Taha Lake scheme costs $10,2 million, shown in Tables 6.1 and 6.2. The first scheme is the more economic and can supply enough energy for both electrical and heating loads for 25 years. However, the system would still require a diesel plant to assist the hydro plant in meeting peak daily loads in the winter.

The effective cost of energy produced by the Rae Lake-Lac Ste Croix is 17,6 ¢/kWh. When compared to an equivalent cost under the existing energy systems of only 10,8 ¢/kWh, it must be concluded that the project is not economically viable.

6.5 ALTERNATIVE ENERGY SOURCES

6.5.1 Wood

Space heating is presently supplied by wood and will likely continue to be an important fuel source.

6.5.2 Wind

The cost of wind energy at Rae Lakes was estimated to be 62,7 ¢/kWh at 6% discount rate, and it is therefore not a viable alternative.

6.6 CONCLUSION

Small hydro or wind generators are not economically viable alternatives to diesel generated electricity or wood generated heat at Rae Lakes. It would appear, at this time, that the present energy systems being used at Rae Lakes provide the optimum solution to the energy needs of the community.

TABLE 6.1

PROJECT COST (1984 dollars)

RAE LAKE - STE-CROIX

		Millions of $	Millions of $
1.	Camp facilities	0.147	
2.	Dams and diversion	0.171	
3.	Spillway	--	
4.	Water conveyance system	0.767	
5.	Powerhouse	0.179	
6.	Access	0.106	
7.	Transportation	0.073	
8.	Sub-total of Civil Works (C.W.)		1.443
9.	Electrical and Mechanical		
	- Equipment	0.361	
	- Services	0.053	
	- Erection	0.061	
10.	Transmission	0.900	
11.	Sub-total of E&M		1.375
12.	Contingencies		
	- Civil (20%)	0.289	
	- E&M (8%)	0.110	
13.	Engineering (10%)	0.322	
14.	Sub-total of Direct Cost	3.539	
15.	Indirect Costs (45% of C.W.)	0.649	
16.	Capital Cost	4.188	
17.	Interest during construction (6%)	0.251	
18.	Construction Cost	4.439	
19.	Unit Cost	$17 759/$W	

Notes: 1) Estimated capital costs are ± 20% in accuracy
2) Does not include costs for feasibility and environmental studies.

TABLE 6.2
PROJECT COST (1984 dollars)
RAE LAKE - TAKA

		Millions of $	Millions of $
1.	Camp facilities	0.431	
2.	Dams and diversion	0.485	
3.	Spillway	--	
4.	Water conveyance system	2.623	
5.	Powerhouse	0.380	
6.	Access	0.106	
7.	Transportation	0.216	
8.	Sub-total of Civil Works (C.W.)		4.241
9.	Electrical and Mechanical		
	- Equipment	0.739	
	- Services	0.072	
	- Erection	0.094	
10.	Transmission	0.900	
11.	Sub-total of E&M		1.805
12.	Contingencies		
	- Civil (20%)	0.848	
	- E&M (8%)	0.144	
13.	Engineering (10%)	0.704	
14.	Sub-total of Direct Cost	7.742	
15.	Indirect Costs (45% of C.W.)	1.908	
16.	Capital Cost	9.650	
17.	Interest during construction (6%)	0.579	
18.	Construction Cost	10.229	
19.	Unit Cost	$20 458/kW	

Notes: 1) Estimated capital costs are ± 20% in accuracy
2) Does not include costs for feasibility and environmental studies.

SECTION 7 - RANKIN INLET

7.1 COMMUNITY SETTING

Rankin Inlet is an Inuit community of 1210 people and it is located on the west coast of Hudson Bay. Rankin Inlet was established as a mining centre in 1955 by North Rankin Nickel Mines, but the mine closed in 1962 causing considerable hardship to those employed at the mine. It is only in the past decade that the community has recovered somewhat by operating a fishery, crafts industry and receiving territorial government investment, through the relocation of government offices from Churchill to Rankin Inlet.

The economic base of Rankin Inlet is a mixture of wage and traditional employment. Government, transportation and commercial fishing provide most of the wage employment although tourism is becoming more important each year. Traditional harvesting includes arctic char, grayling, lake trout and white fish as well as whales, walrus, caribou, polar bear, and fur bearing animals. The commercial fishery processes arctic char.

7.2 ENERGY DEMAND AND SUPPLY

The community presently receives electricity from diesel generators which have a total capacity of 2 720 kW. The electrical load in 1982/83 amounted to 6 478 MWh with a load factor of 61%. Annual growth over the past 6 years averaged 7,0%.

Space heating is supplied by oil furnaces and a heat recovery system from the NCPC diesel generators. In 1978/79, 64 839 gallons of heating oil were consumed. This is equivalent to approximately 17 750 MWh of heat as an electrical load and it is roughly 3,4 times the normal electrical load.

Both the historic and forecasted energy consumption for Rankin Inlet is presented in Figure 7.1 which shows that the total energy consumption could more than double over the next 40 years.

Figure 7.2 shows the load shape and the fact that the peak load occurs in January of each year. To meet the energy requirements of the combined electric and heating loads to year 2024, a 20,5 Megawatt hydro plant would be required. To supply the electrical load only a 3,5 Megawatt plant would be needed.

7.3 PROJECT DESCRIPTION

The development which was proposed is shown in Figure 7.3. The project involved the diversion of flows from Gibson Lake into Diana Lake via Peter Lake. The natural head is obtained by taking advantage of three small lakes which are perched above the Diana river. A canal would have linked the intake in a dam across the Diana river to these three lakes, which may possibly need deepening. The lakes would have been used as a forebay and water would have been taken to the powerhouse on the right bank of the Diana river, Figure 7.4. The installed capacity of the plant would have been 3 Megawatts.

Additional flow could be obtained by diverting the Meliadine River and lake into Peter Lake, but the increase in the average flow was estimated to be no more than 2,3 m^3/s; this is less than 10% of the average flow obtainable from Gibson Lake and the Diana river system. The cost of this diversion was therefore not investigated.

Spring and summer flows would have been stored behind the dam to be released for use in the winter. The construction of a dam at the outlet of Gibson lake to permit the diversion would raise the natural water level by 8,1 m. The natural water level in the Diana river at the dam site would be raised by about 4,5 m.

7.4 ENVIRONMENTAL IMPACT

Environmental concerns over the project at Rankin Inlet were focussed almost exclusively on the Diana River char fishery.

7.4.1 Impact of Diana River Dam

The bulk of the char caught in the offshore fishery originate in the Diana river (Dept. of Fisheries and Oceans, ref. 1). This fishery is therefore dependent on keeping intact the historical sequence of migratory movements into and out of the Diana river. Little is definitely known about the char movements, but it is probable that overwintering occurs in upstream lakes such as Peter Lake and Diana Lake; both lakes have commercial quotas for char. Spawning may also take place in these lakes. The dam would not only enlarge and deepen Diana Lake but it would prevent the access of fish migrating from coastal waters into these upstream areas, unless a fishway was provided. As outlined for the Coppermine river, no documentated cases of char fishways are known, but it is considered that the development of a successful fishway is feasible. Fisheries studies, however, would be required to provide data necessary for designing the fishway. The kinds of information which would be collected are:

- size of the run;
- size range of fish;
- species of fish (whitefish runs may also exist);
- duration of run.

7.4.2 Impact of Gibson Lake Dam

The Gibson Lake Dam would increase the surface area and depth of Gibson Lake and increase the flows through Peter Lake, Diana Lake and the smaller lakes along the Diana river. These changes do not appear to have potentially serious impacts on fisheries in the present Diana river system. However, major changes to the fish populations in Gibson Lake and the unnamed river which drains Gibson Lake are possible.

The unnamed river appears to support a population of Arctic char, since there is a commercial quota for this species at its mouth at Chesterfield Inlet. Machum Lake and Macquoid Lake are also located on the river and have commercial quotas for lake trout and whitefish. Although the magnitude of the flow reduction in the unnamed river has not yet been determined, there is a potential for significant impacts on the fish populations. For example, the severe reduction in flow may make some stream sections impassible at the time of upstream migration (fall for char and whitefish).

7.4.3 Environmental

A detailed knowledge of the river channel (locations and configurations of rapids, etc.) and projected seasonal flows would be required to assess the possibility of this type of impact and the potential for mitigation. Fishways can be built at natural obstructions but construction costs may be very high due to access to remote areas.

Flow reductions may also result in subtle changes in lake habitat which could affect fish production.

There is a possibility of major changes in the fish species composition of Gibson Lake due to:

- removal of the connection with the unnamed river;
- connection with the Diana River drainage;
- increase in mean and surface area.

To fully assess project impacts on Gibson Lake and the unnamed river drainage system, extensive field studies would be required. These would:

- describe the existing fish populations which are presently unknown;
- determine movements between parts of the drainage and between the river and coastal waters;
- determine whether any obstructions to migration would exist under altered flow regimes.

The wildlife species of primary importance is the barren-ground caribou. At the present time there is insufficient information to assess whether or not this species would be affected by the project. Since the main concern is the possibility of interference with migrations, it will be necessary to determine the locations and times at which caribou cross the two affected drainage basins. It will also be necessary to determine if the project will change the pattern of ice formation and break-up at these locations enough to interfere with caribou crossing.

No detailed information on the use of the project areas by other wildlife species is available.

7.5 PROJECT VIABILITY

Even though the Gibson-Diana scheme appeared initially to be economically viable, the entire project rested upon

1) the ability to divert water from the Gibson Lake drainage basin into the Diana River, and

2) the establishment of sufficient head at the Diana River powerhouse to produce the required 3 Megawatts.

Field investigations confirmed that the necessary elevation drop at the Diana Dam powerhouse site could be achieved, Figure 7.4. However, it is highly unlikely that water can be transferred from Gibson Lake to Diana Lake, Figure 7.5, due to topographic limitations. Without this transfer of 70% of river flow required, the project cannot meet even the electric load.

Before the field survey was done, the Rankin Inlet scheme (3 Megawatts) was estimated to cost $25 million. The energy which it was thought could be generated was capable of meeting the electrical needs for 40 years, and would have cost 19,5 ¢/kWh. The equivalent cost of diesel generation is 23,1 ¢/kWh. However, since the field survey showed that water cannot be diverted to the Diana river, this energy cost is not valid and, indeed, the entire scheme is physically not feasible.

7.6 ALTERNATIVE ENERGY SOURCES

The energy source which may have the best potential for development in Rankin Inlet is wind. A diesel/wind farm hybrid system would have to be used, since wind on its own would not be reliable. A preliminary investigation has indicated that wind energy at Rankin Inlet, based on wind data for Chesterfield Inlet, could cost about 17,0 ¢/kWh at 6% p.a. discount rate. The cost of energy in a diesel-wind system would have to be evaluated, but before this could be done, site specific with data should be collected over a period of at least one year. The data which was used in obtaining the above cost of wind energy is not good enough for a feasibility study.

7.7 CONCLUSIONS

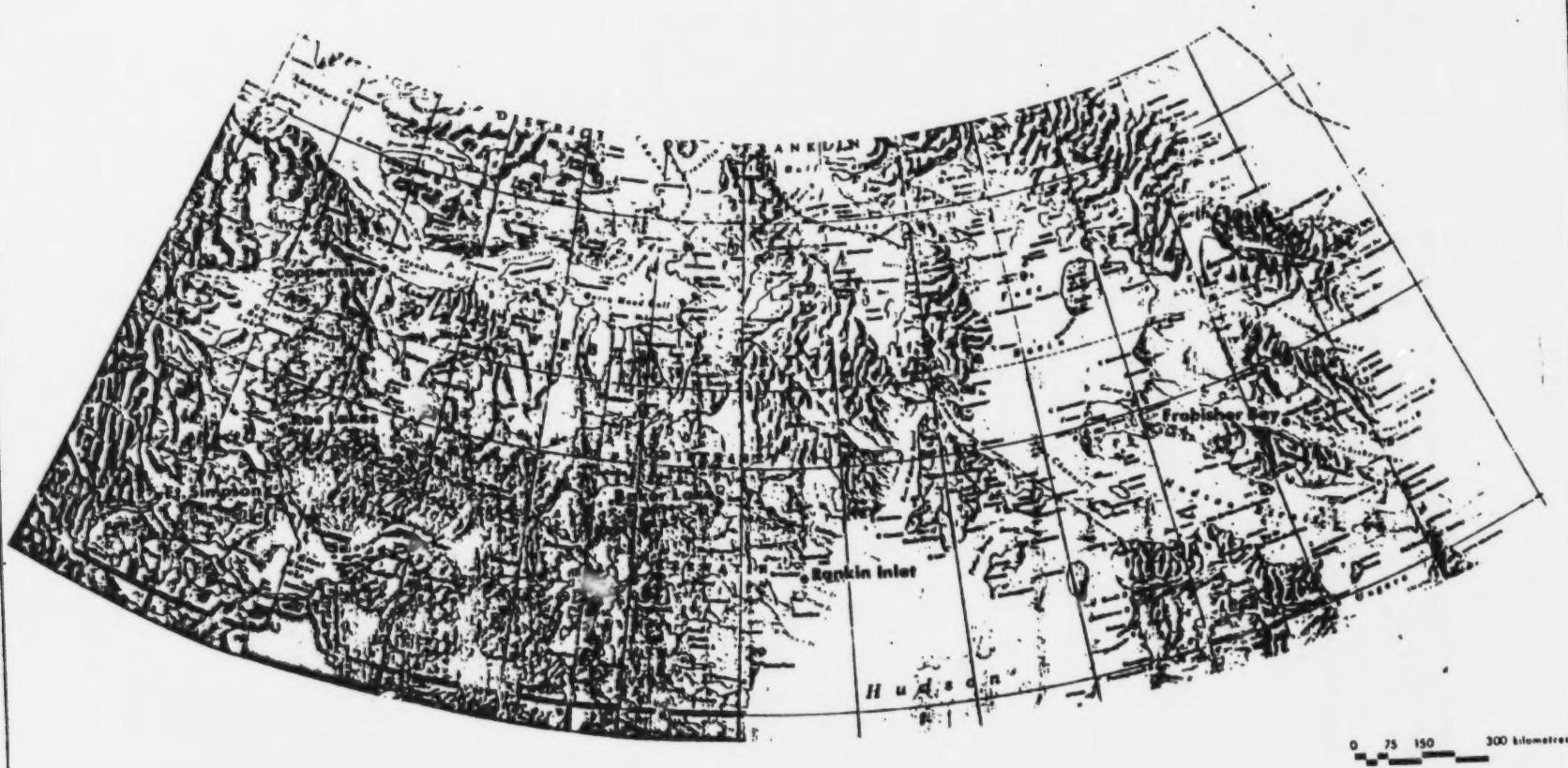
1) A small hydro scheme on the Diana River is not economically viable due to insufficient flows of water in the Diana River.

2) Diversion of water from Gibson Lake to the Diana River basin is highly unlikely based on field surveys.

3) The environmental impact upon the char fishery of the Diana River would be of paramount concern.

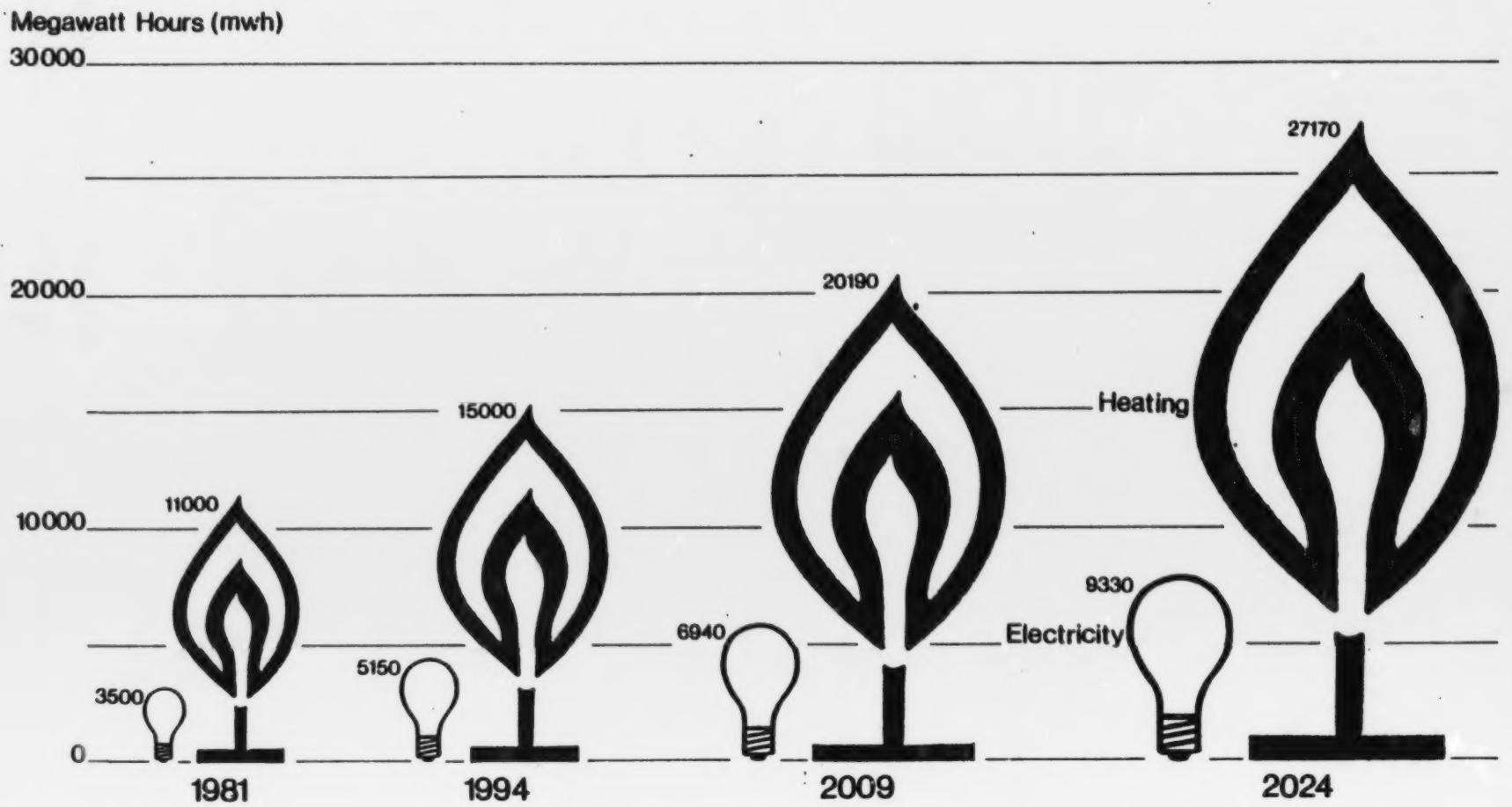
4) A wind/diesel hybrid electrical power system should be investigated further after site specific wind data is collected.

FIGURE 1.1



LOCATION OF STUDY AREAS

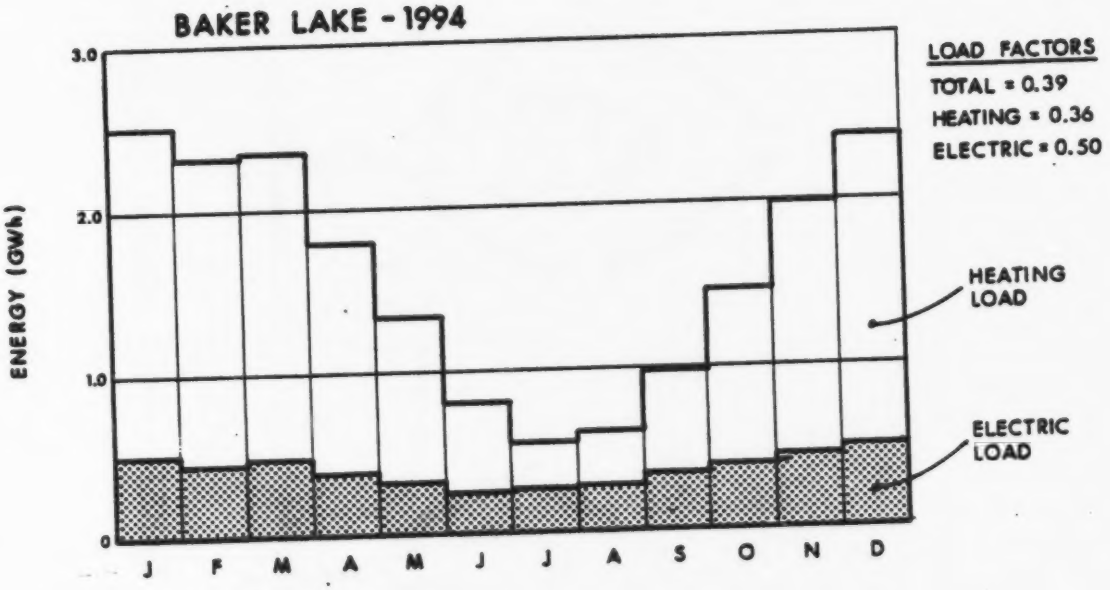
hydrowest consultants inc.



BAKER LAKE: ANNUAL ENERGY CONSUMPTION

FIGURE 2.1

FIGURE 2.2



BAKER LAKE - 1994
MONTHLY LOADS

FIGURE 2.3

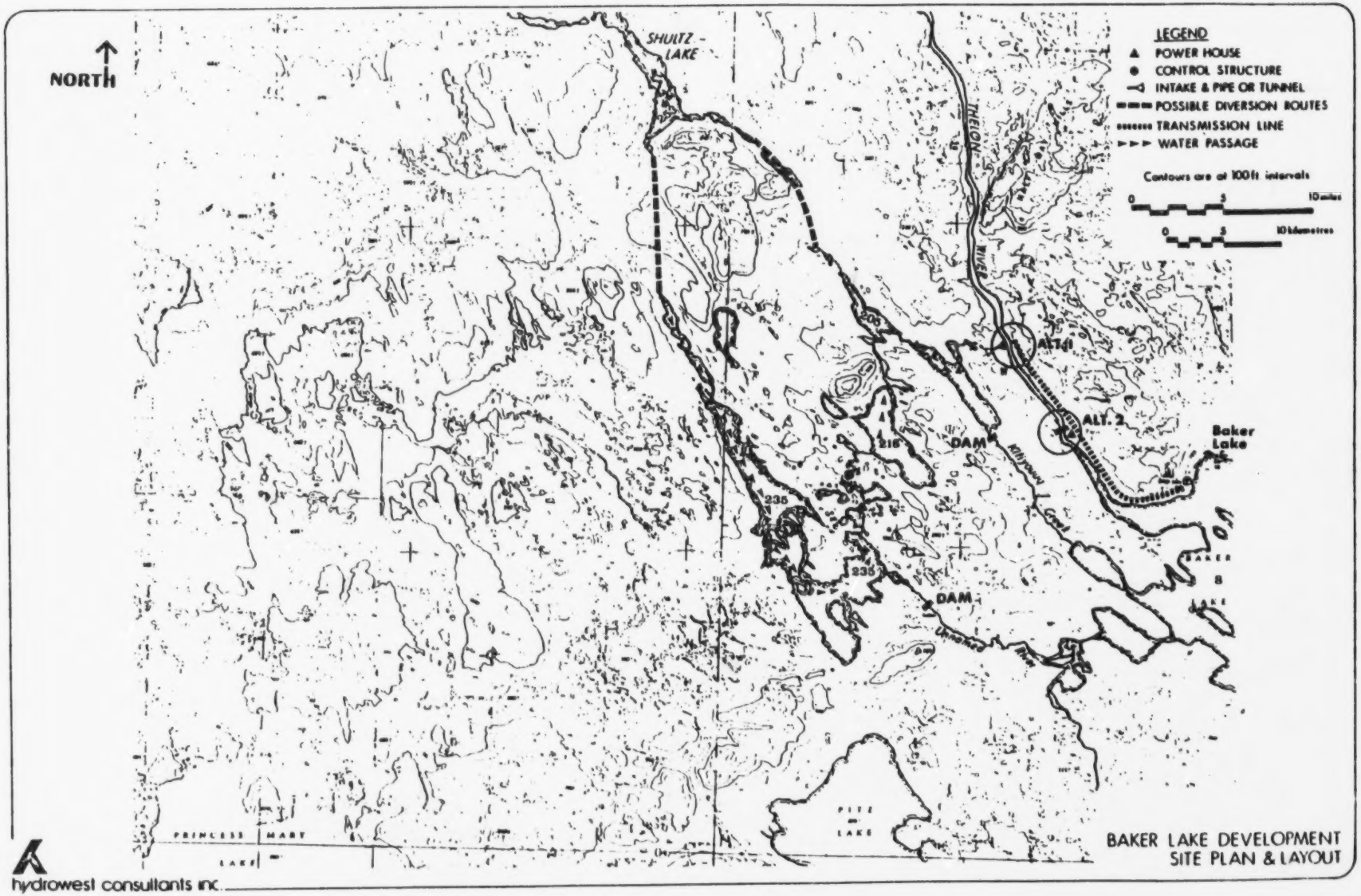
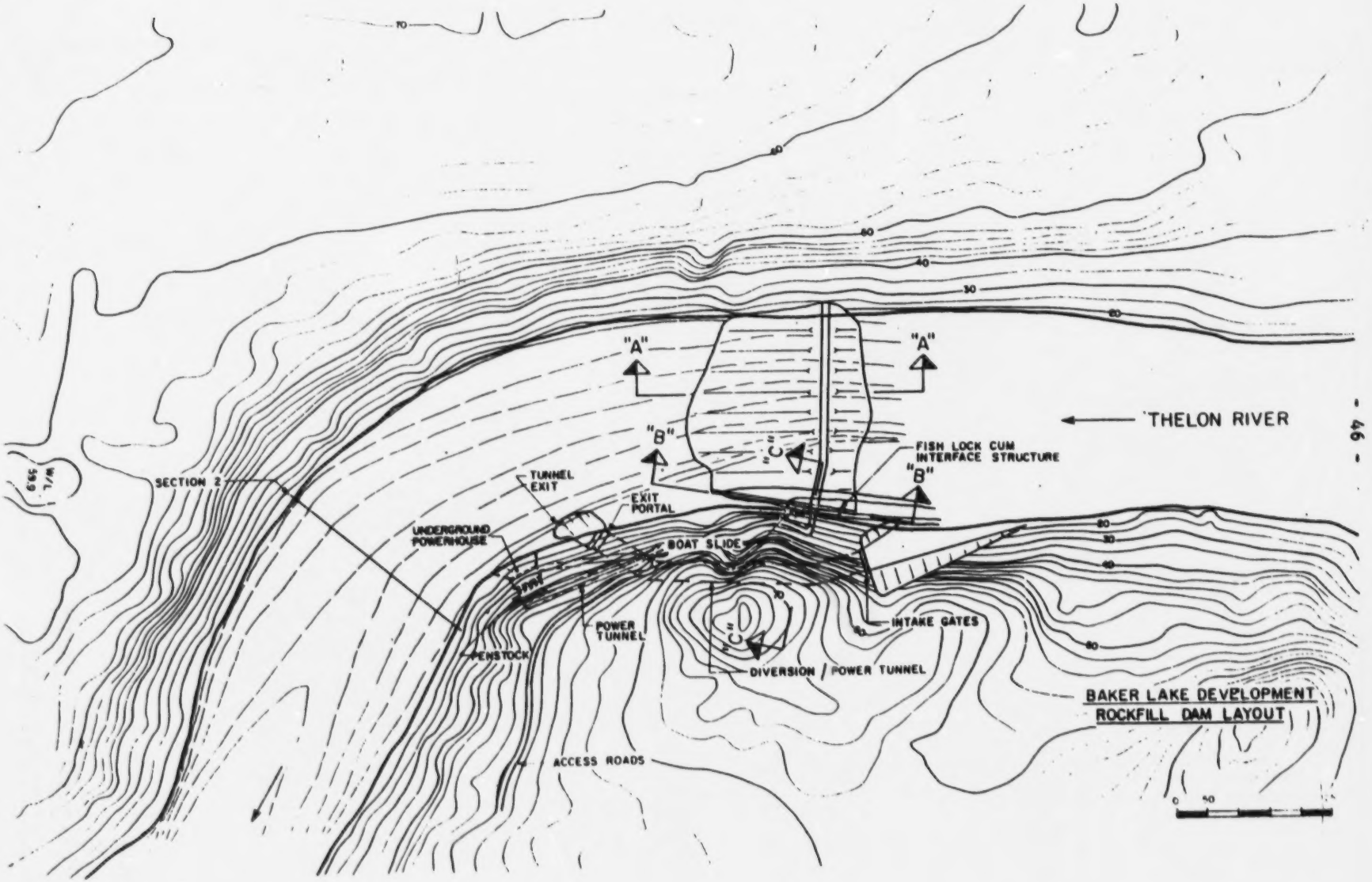
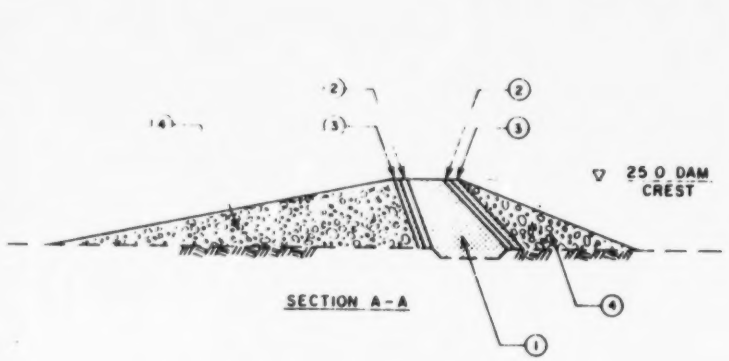
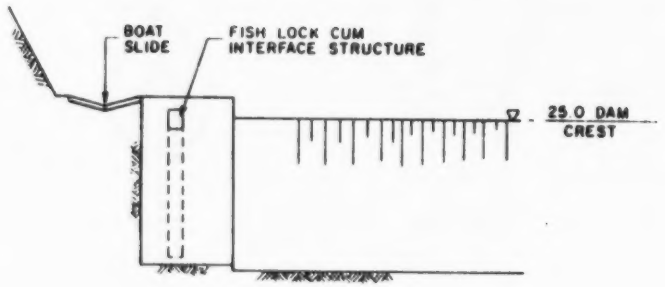

NORTH
SHULTZ LAKE
THELON
RIVER
LEGEND
POWER HOUSE
CONTROL STRUCTURE
INTAKE & PIPE OR TUNNEL
POSSIBLE DIVERSION ROUTES
TRANSMISSION LINE
WATER PASSAGE
Contours are at 100ft intervals
0 5 10 miles
0 5 10 kilometres
ALT. 1
ALT. 2
DAM
DAM
Baker Lake
Kazan River
Chesterfield Inlet
BAKER LAKE
PRINCESS MARY LAKE
PLEE LAKE
BAKER LAKE DEVELOPMENT
SITE PLAN & LAYOUT
hydrowest consultants inc.

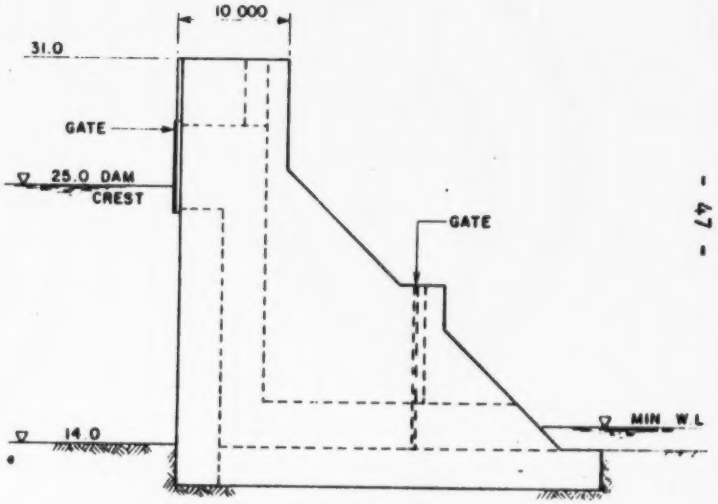
FIGURE 2.4


70
60
50
40
30
20
"A"
"A"
"B"
"B"
"C"
"C"
THELON RIVER
FISH LOCK CUM
INTERFACE STRUCTURE
SECTION 2
TUNNEL
EXIT
EXIT
PORTAL
UNDERGROUND
POWERHOUSE
BOAT SLIDE
POWER
TUNNEL
PENSTOCK
INTAKE GATES
DIVERSION / POWER TUNNEL
ACCESS ROADS
BAKER LAKE DEVELOPMENT
ROCKFILL DAM LAYOUT
0
40





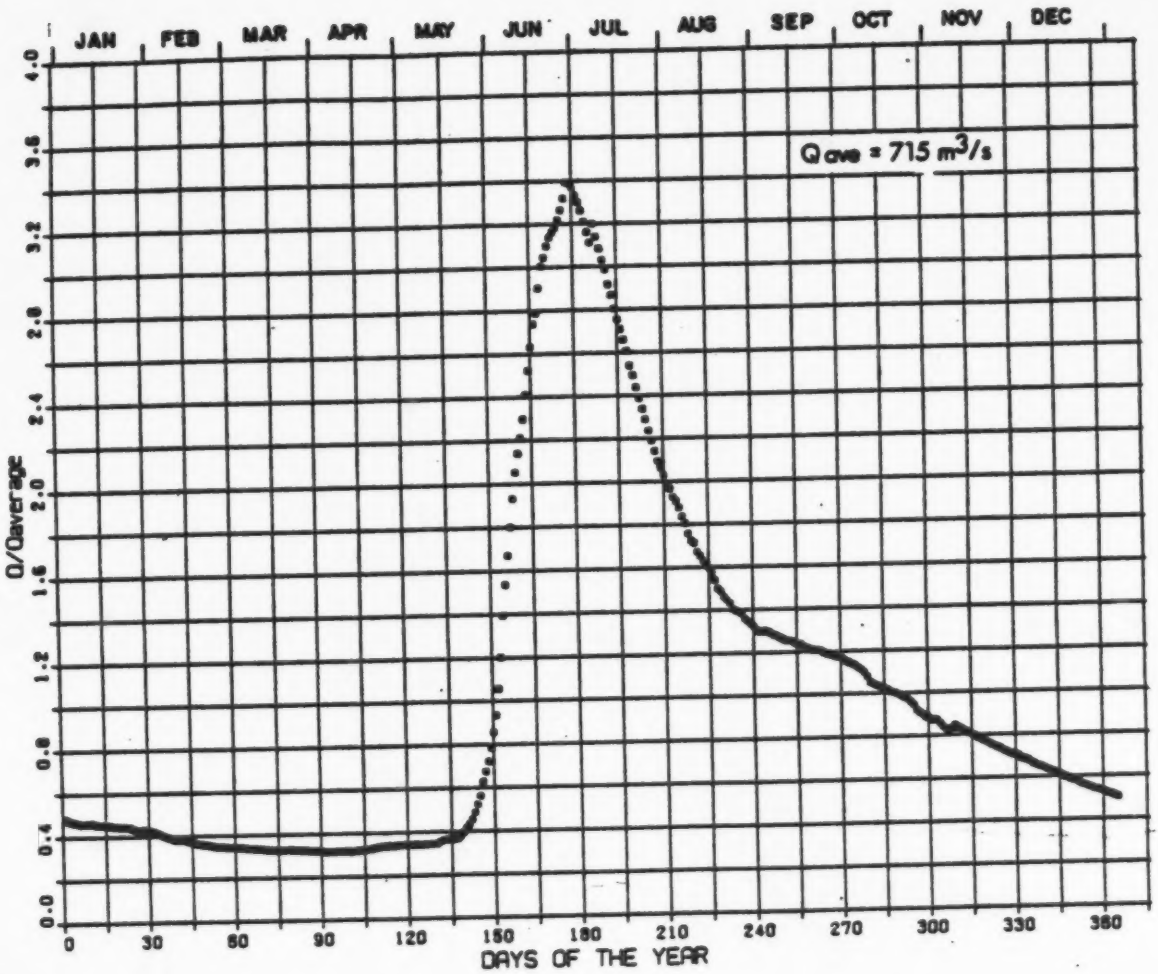
PARTIAL SECTION C-C
FISH LOCK CUM INTERFACE STRUCTURE



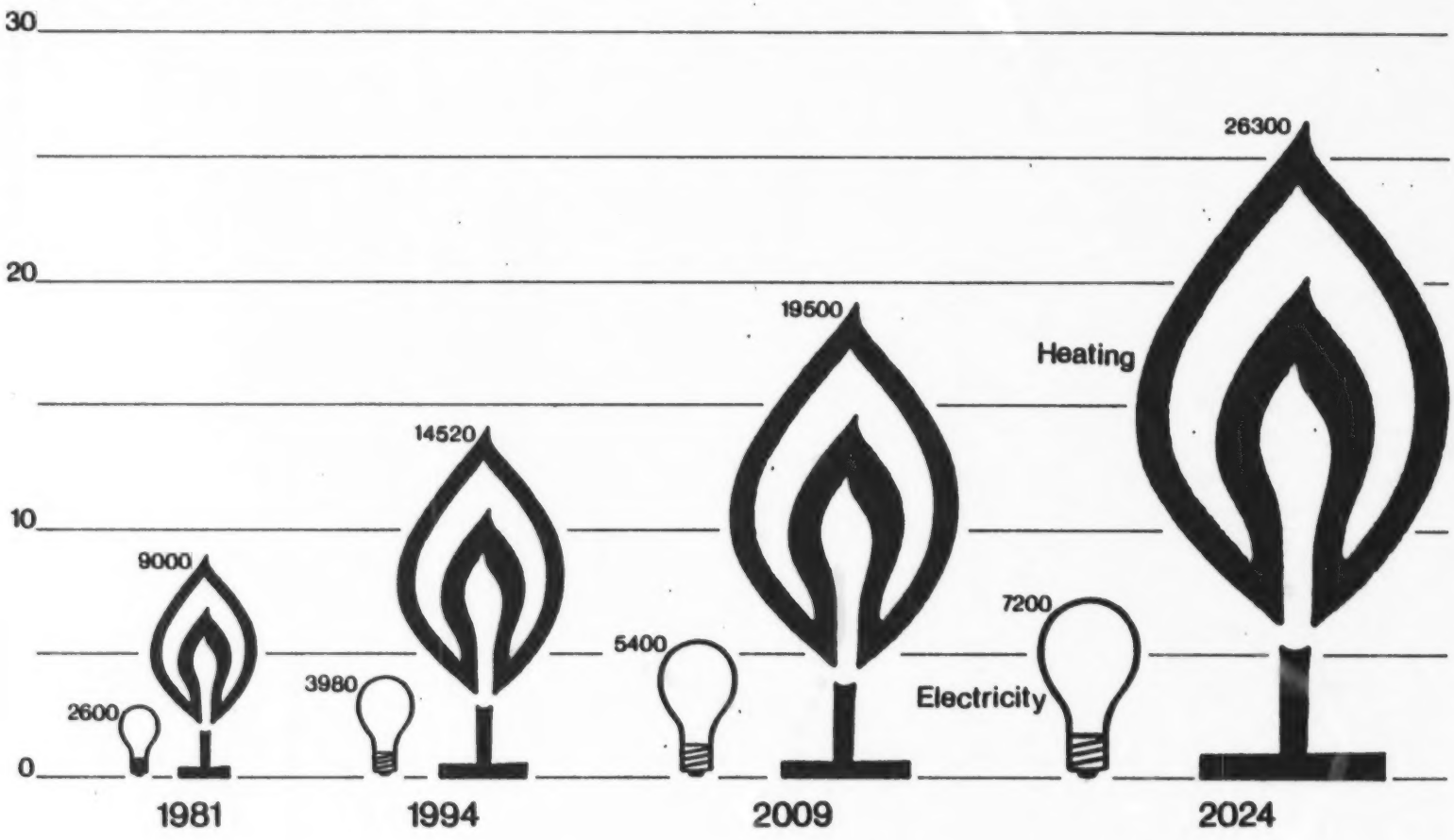
SECTION B-B
FISH LOCK

BAKER LAKE DEVELOPMENT
SECTIONS OF STRUCTURES

FIGURE 2.6



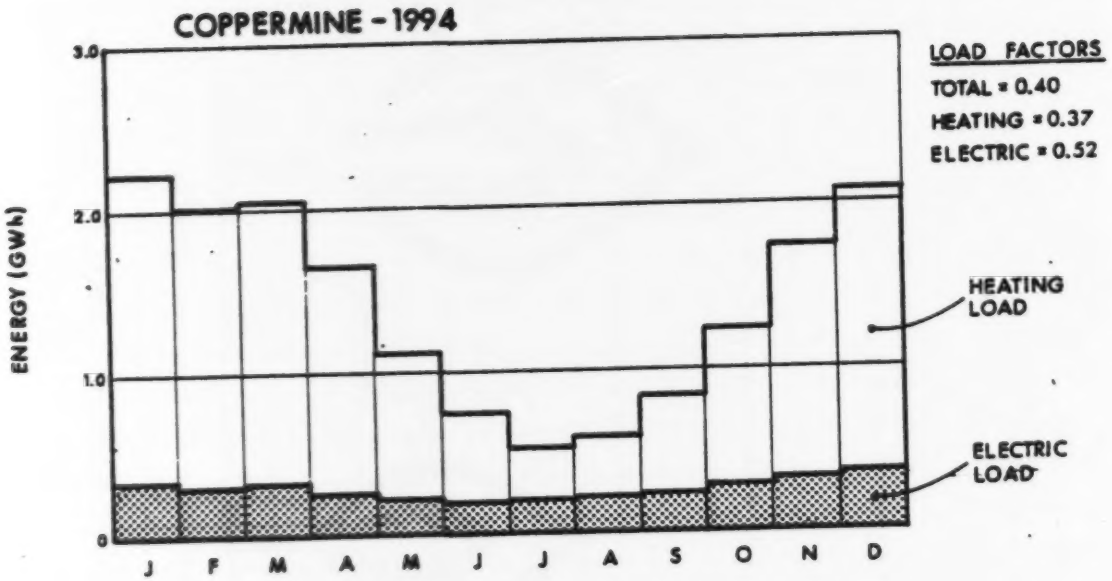
AVERAGE
DIMENSIONLESS DAILY FLOWS
THELON RIVER AT BAKER LAKE



COPPERMINE: ANNUAL ENERGY CONSUMPTION

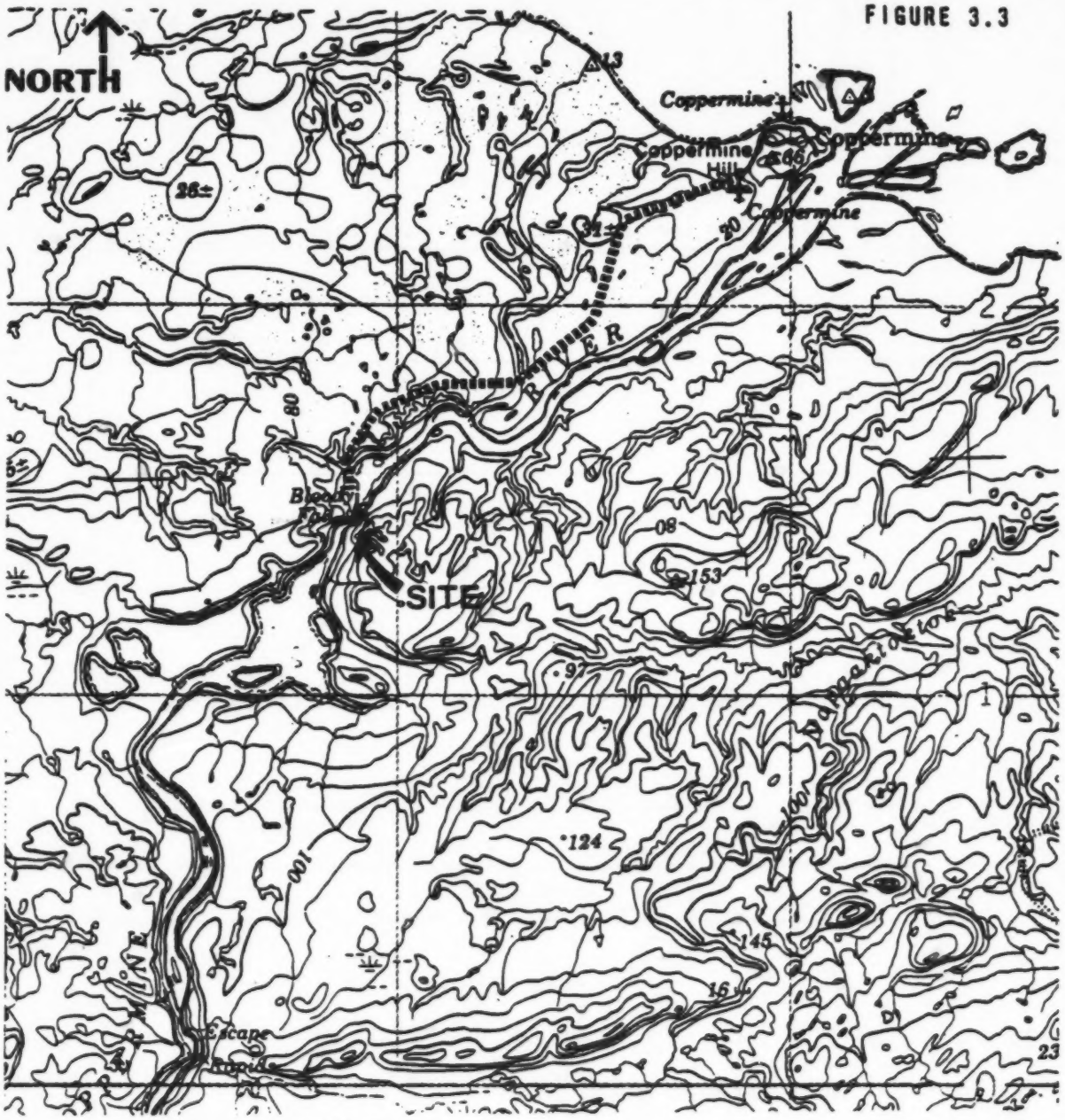
FIGURE 3.1

FIGURE 3.2



COPPERMINE - 1994
MONTHLY LOADS

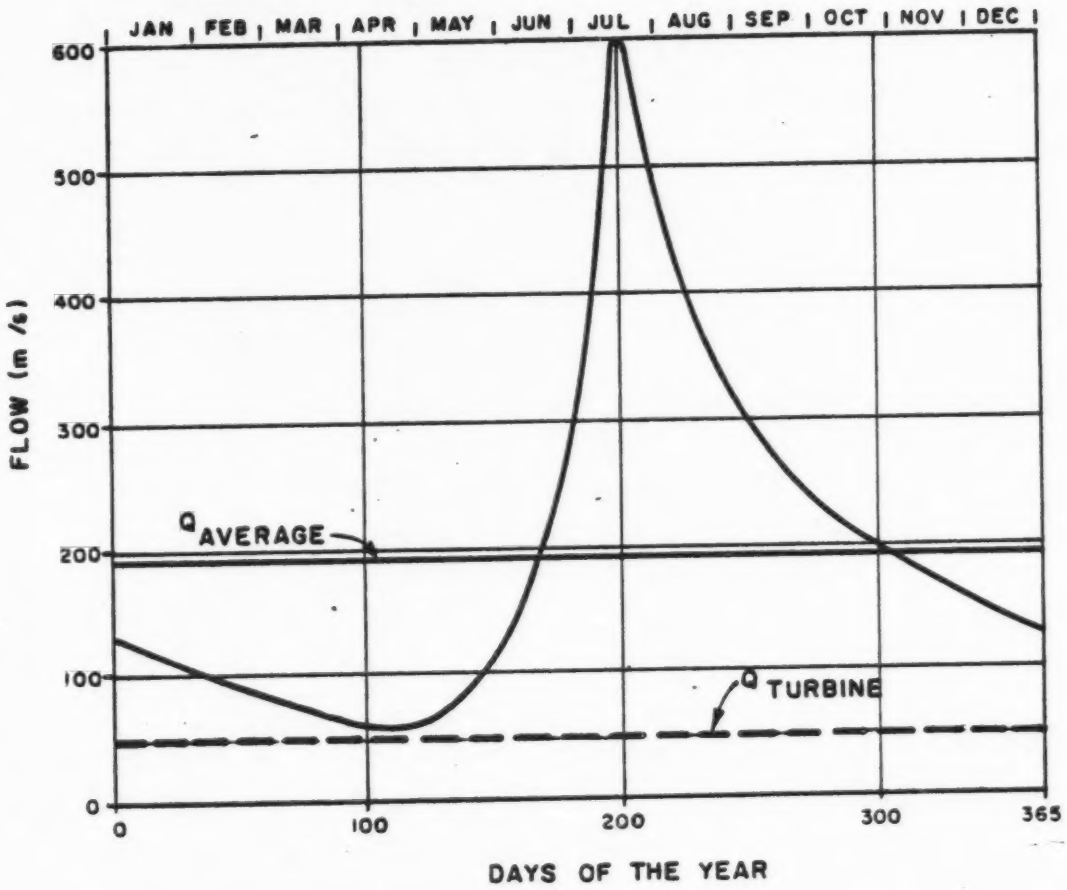
FIGURE 3.3



hydrowest consultants inc.

COPPERMINE DEVELOPMENT
SITE PLAN

FIGURE 3.4



$Q_{AVERAGE} = 191 \cdot 9\ m^3/s$

$Q_{MINIMUM} = 58 \cdot 0\ m^3/s$

$Q_{TURBINE} = 46 \cdot 0\ m^3/s$

COPPERMINE DEVELOPMENT
AVERAGE DAILY FLOWS
COPPERMINE RIVER
AT BLOODY FALLS

FIGURE 3.5

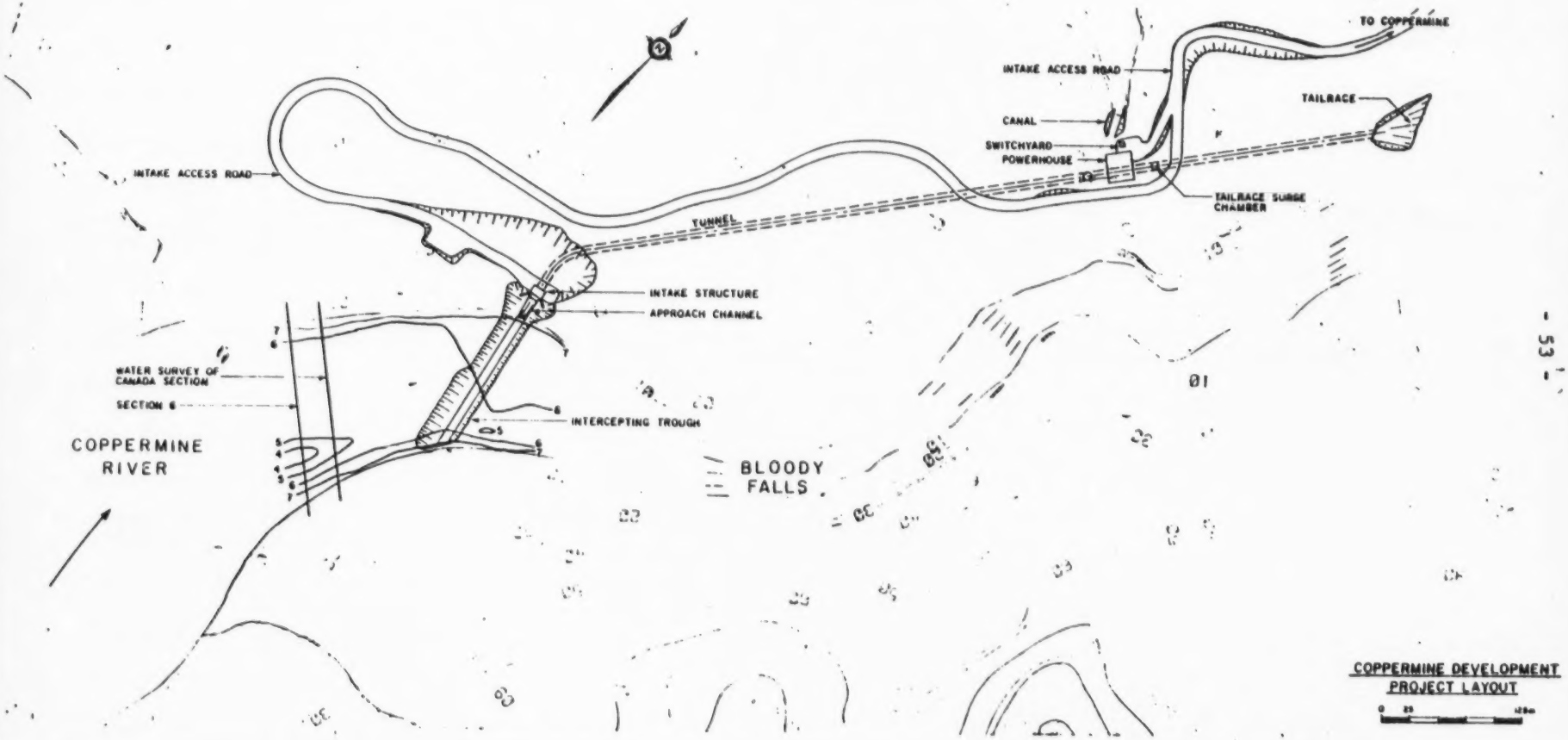
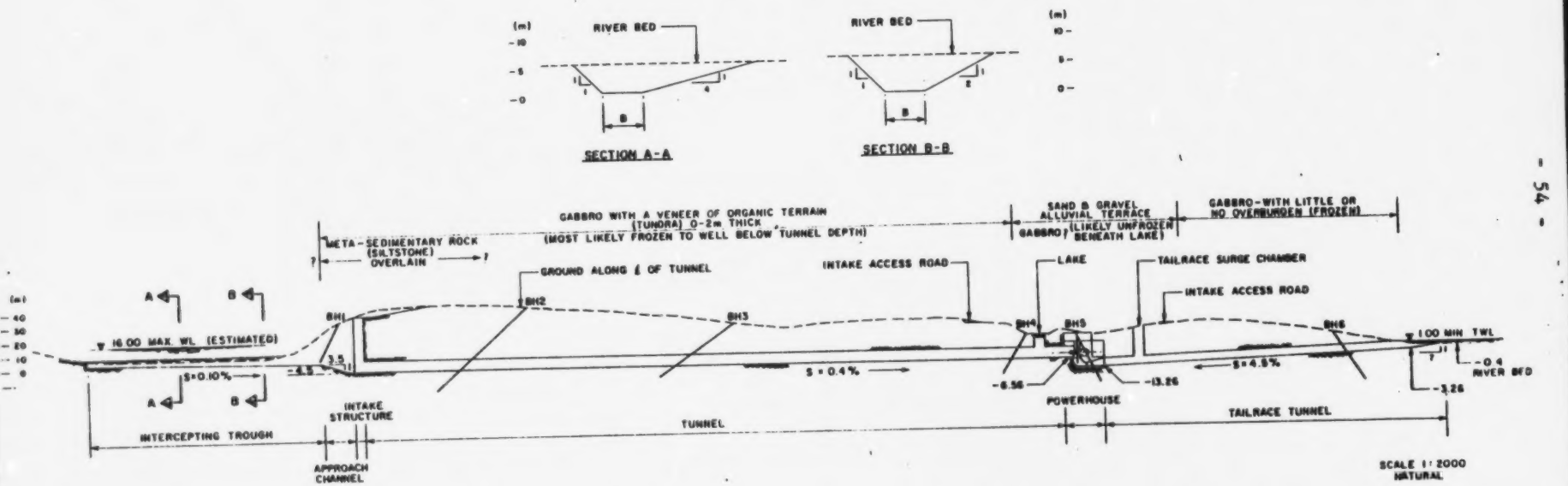
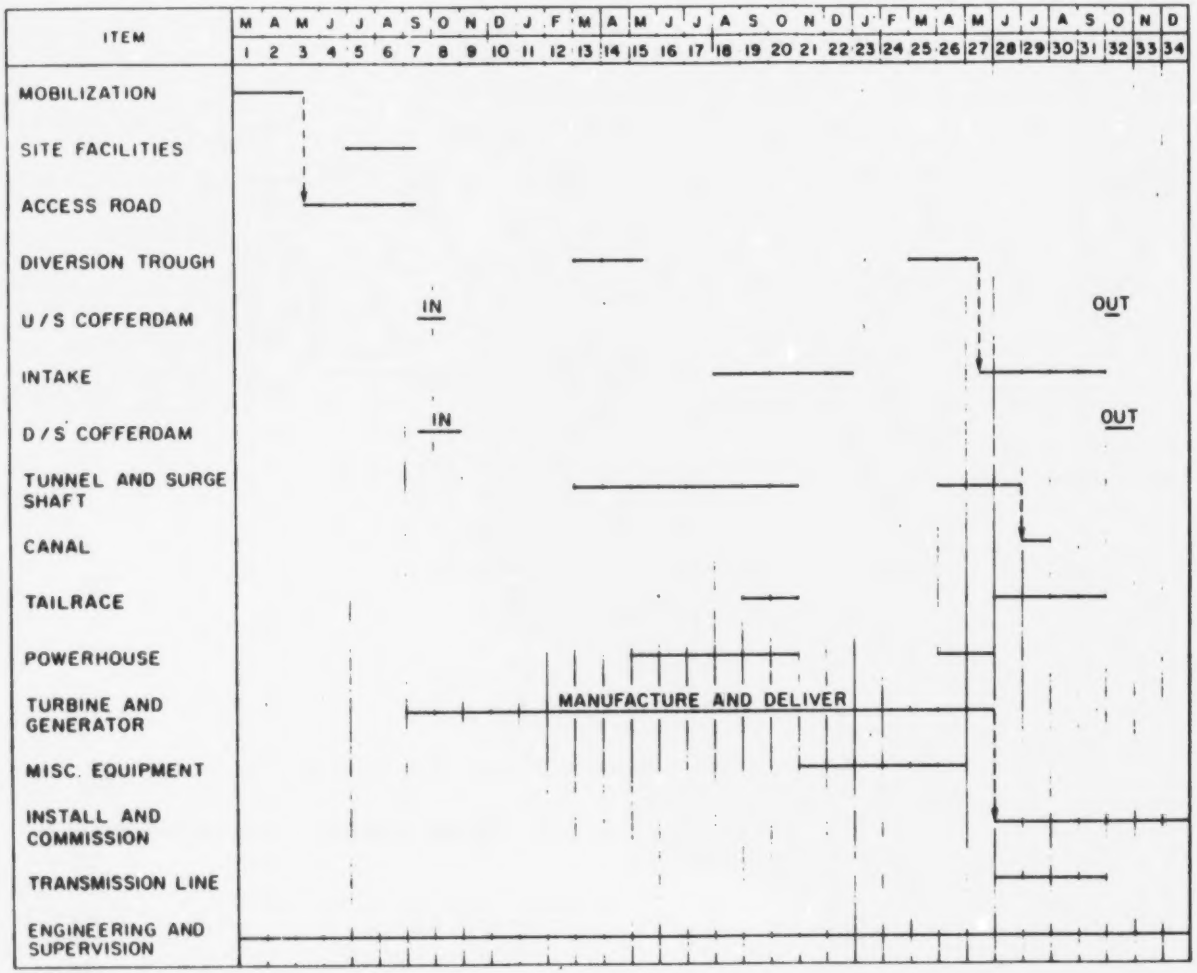

TO COPPERMINE
INTAKE ACCESS ROAD
TAILRACE
CANAL
SWITCHYARD
POWERHOUSE
TAILRACE SURGE CHAMBER
INTAKE ACCESS ROAD
TUNNEL
INTAKE STRUCTURE
APPROACH CHANNEL
WATER SURVEY OF CANADA SECTION
SECTION 6
INTERCEPTING TROUGH
COPPERMINE RIVER
BLOODY FALLS
COPPERMINE DEVELOPMENT
PROJECT LAYOUT

FIGURE 3.6

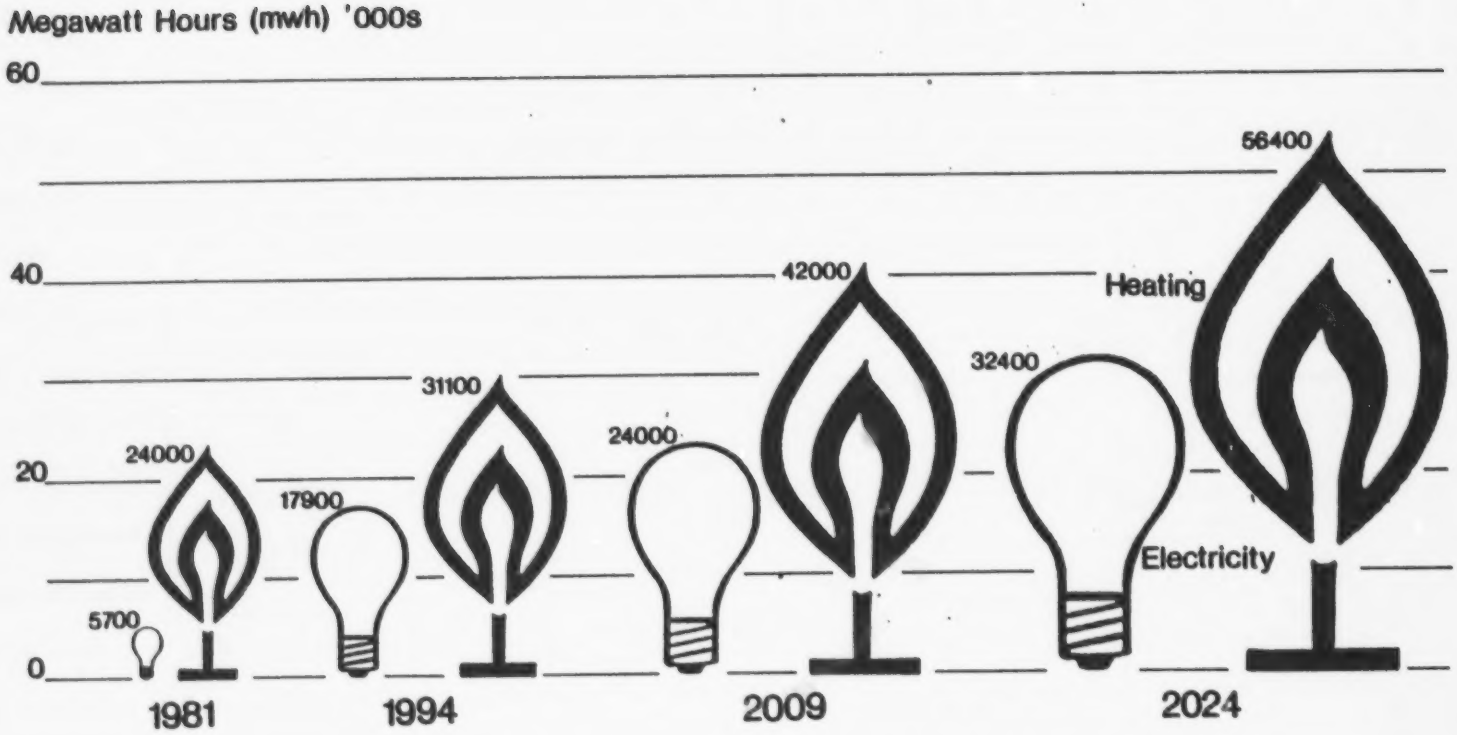


COPPERMINE DEVELOPMENT
DEVELOPED PROFILE ALONG INTAKE TUNNEL AND POWERHOUSE

FIGURE 3.7


ITEM
M A M J J A S O N D J F M A M J J A S O N D J F M A M J J A S O N D
1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 19 20 21 22 23 24 25 26 27 28 29 30 31 32 33 34
MOBILIZATION
SITE FACILITIES
ACCESS ROAD
DIVERSION TROUGH
U/S COFFERDAM
IN
OUT
INTAKE
D/S COFFERDAM
IN
OUT
TUNNEL AND SURGE SHAFT
CANAL
TAILRACE
POWERHOUSE
TURBINE AND GENERATOR
MANUFACTURE AND DELIVER
MISC. EQUIPMENT
INSTALL AND COMMISSION
TRANSMISSION LINE
ENGINEERING AND SUPERVISION

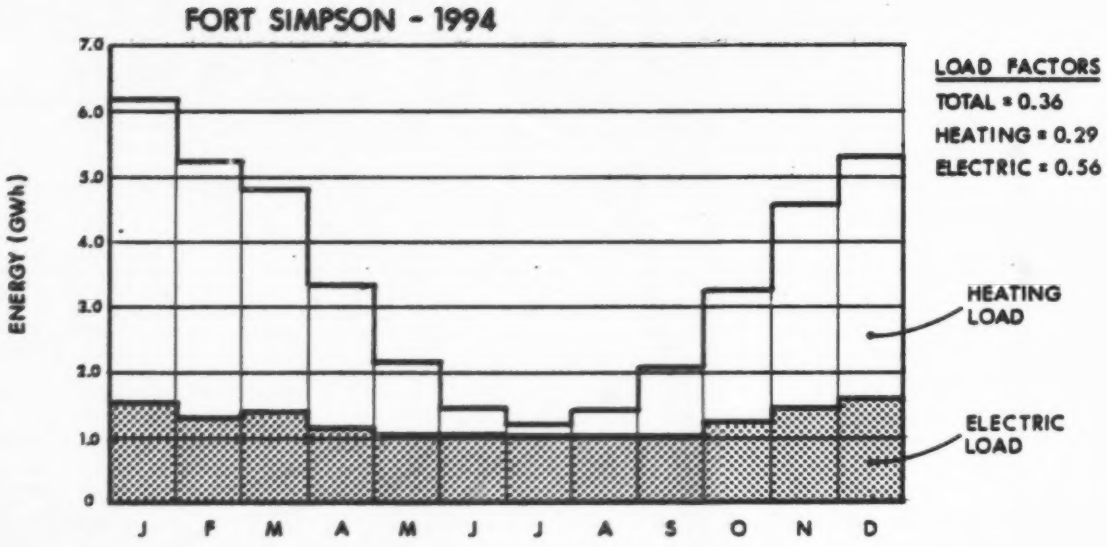
COPPERMINE DEVELOPMENT
CONSTRUCTION SCHEDULE



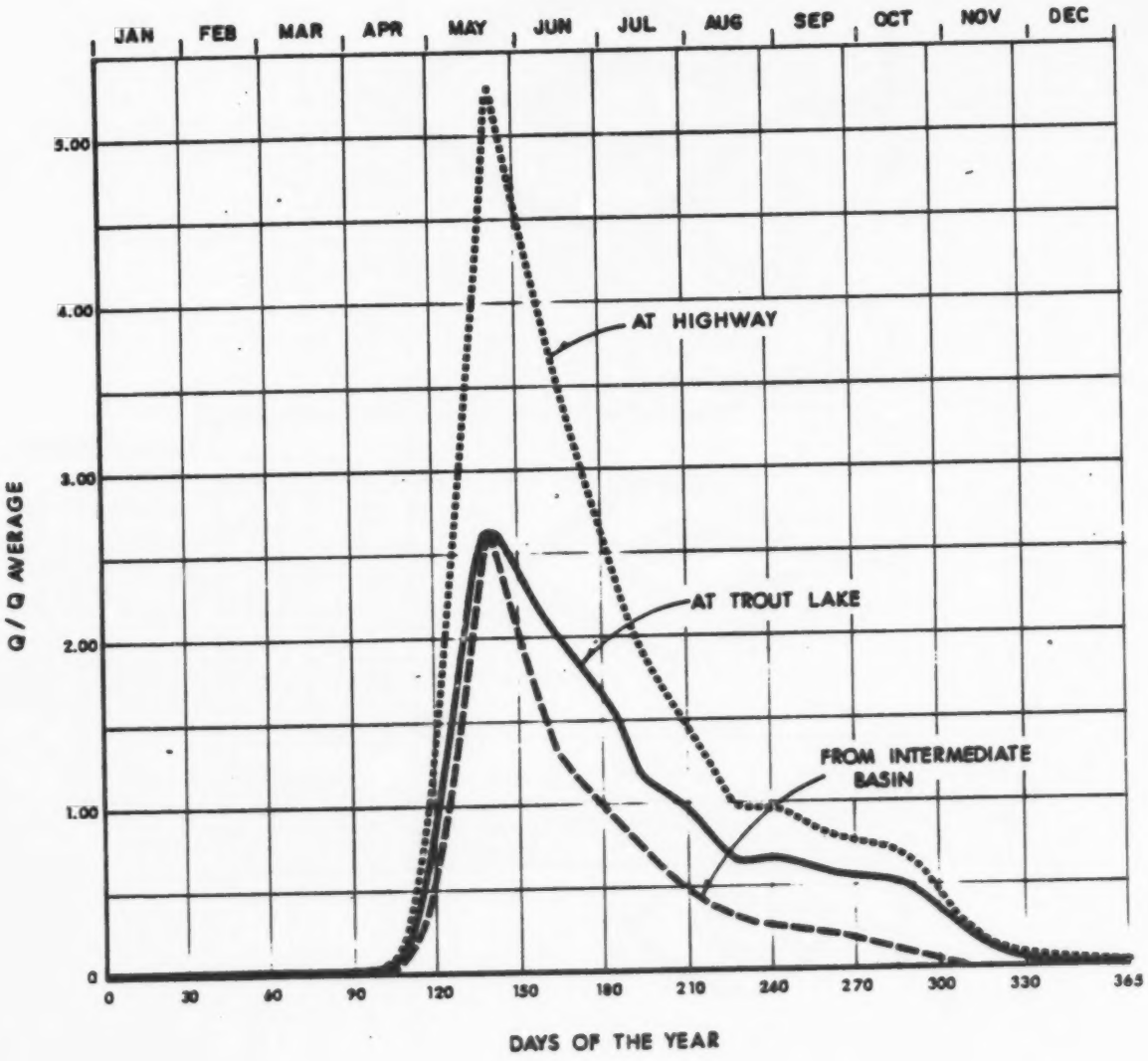
FT. SIMPSON/: ANNUAL ENERGY CONSUMPTION
TROUT LAKE

FIGURE 4.1

FIGURE 4.2



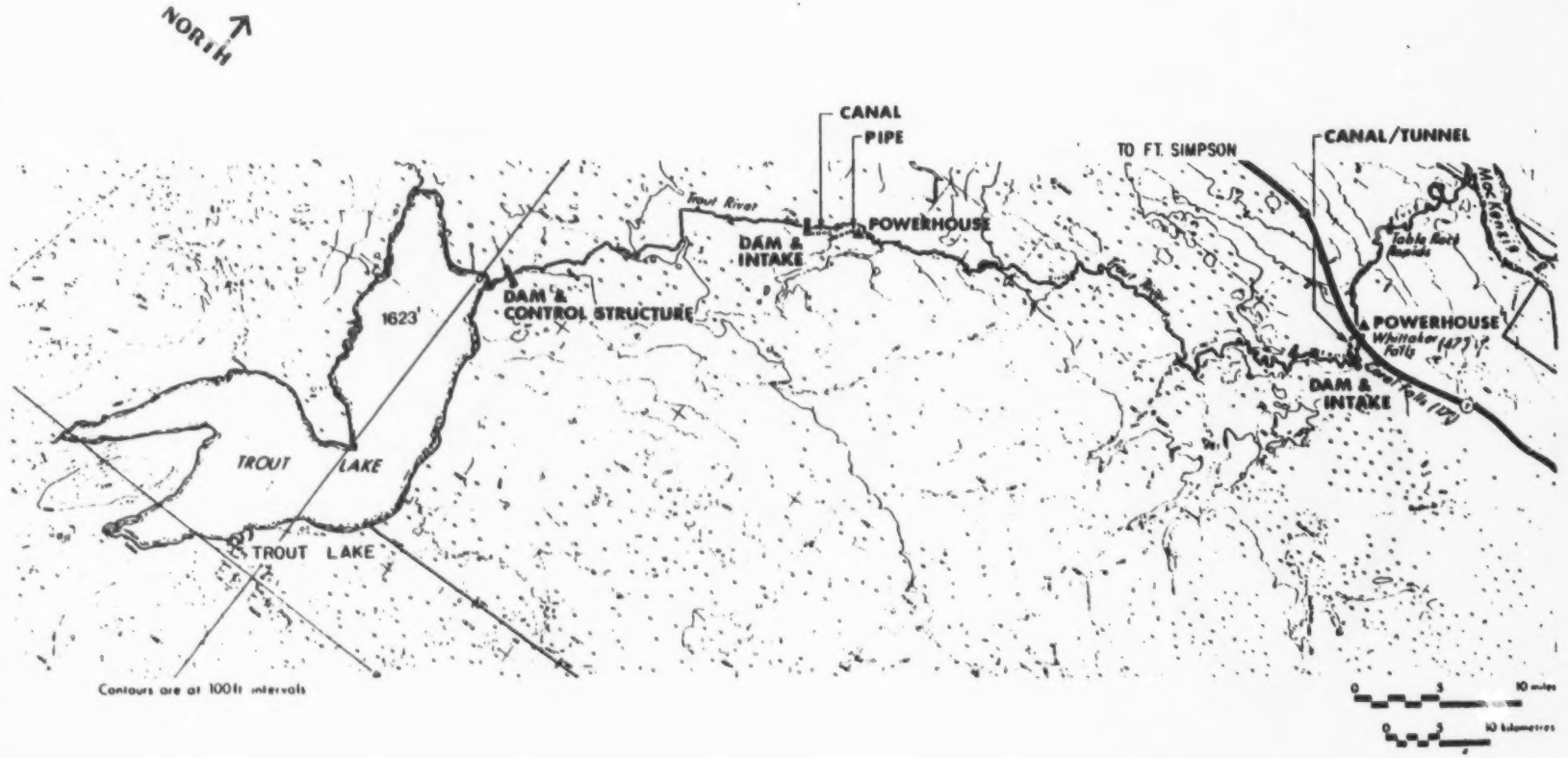
FORT SIMPSON - 1994
MONTHLY LOADS



Q_{av} AT HIGHWAY = 31.91 m^3/s

DAILY FLOWS
IN TROUT RIVER

FIGURE 4.4



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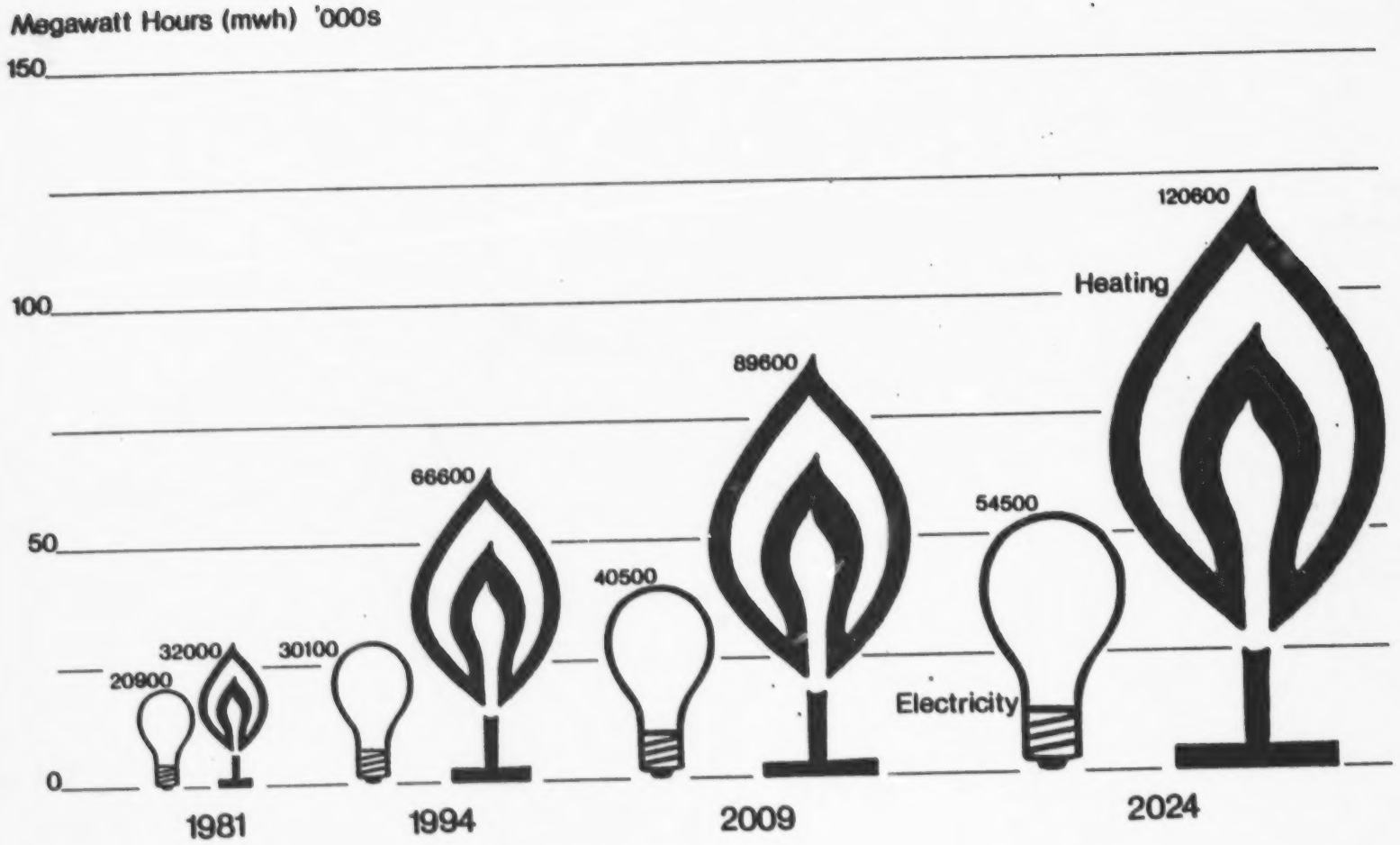
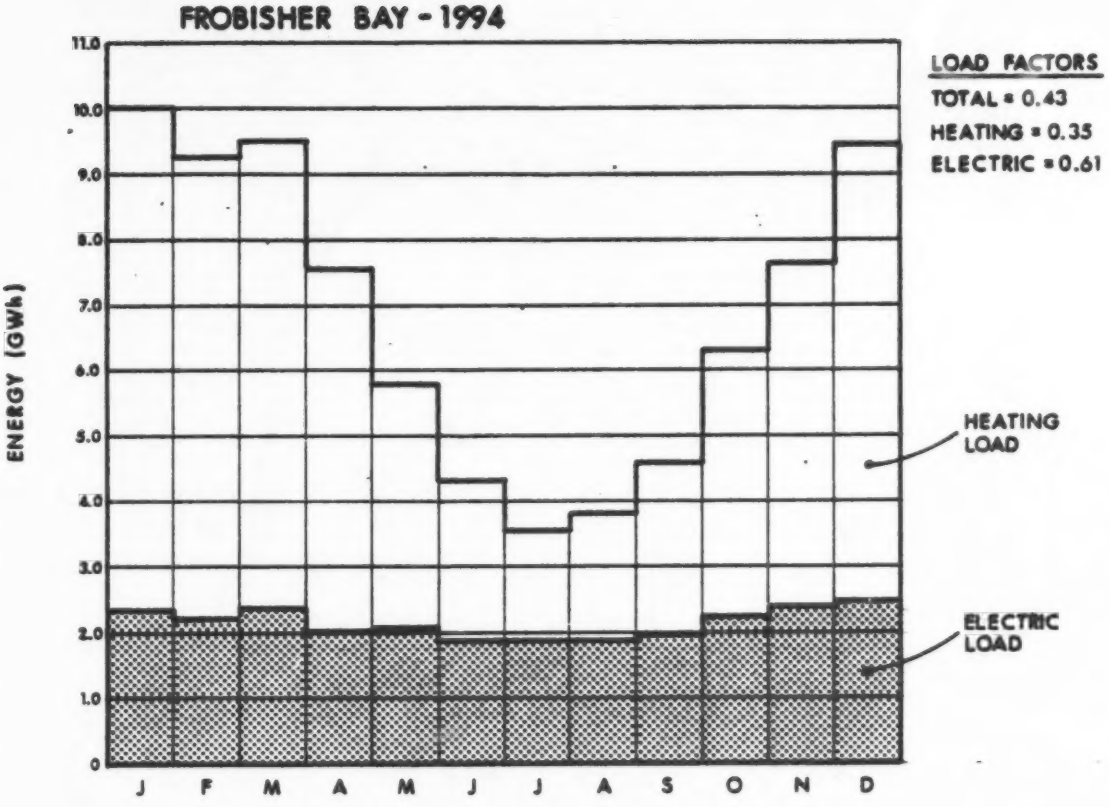
FORT SIMPSON DEVELOPMENT



FROBISHER BAY: ANNUAL ENERGY CONSUMPTION

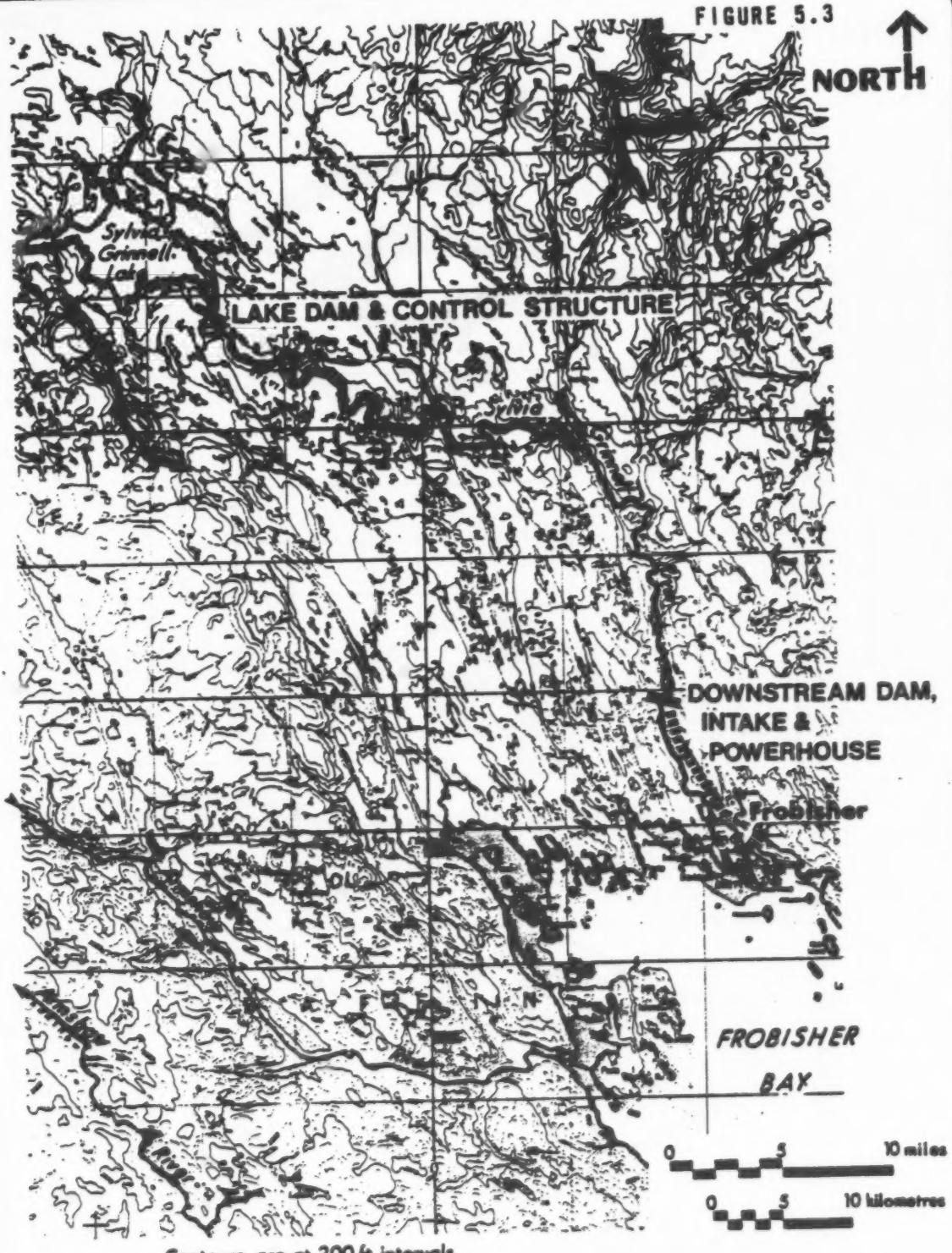
FIGURE 5.1

FIGURE 5.2



FROBISHER BAY - 1994
MONTHLY LOADS

FIGURE 5.3



Contours are at 200 ft intervals

TRANSMISSION LINE

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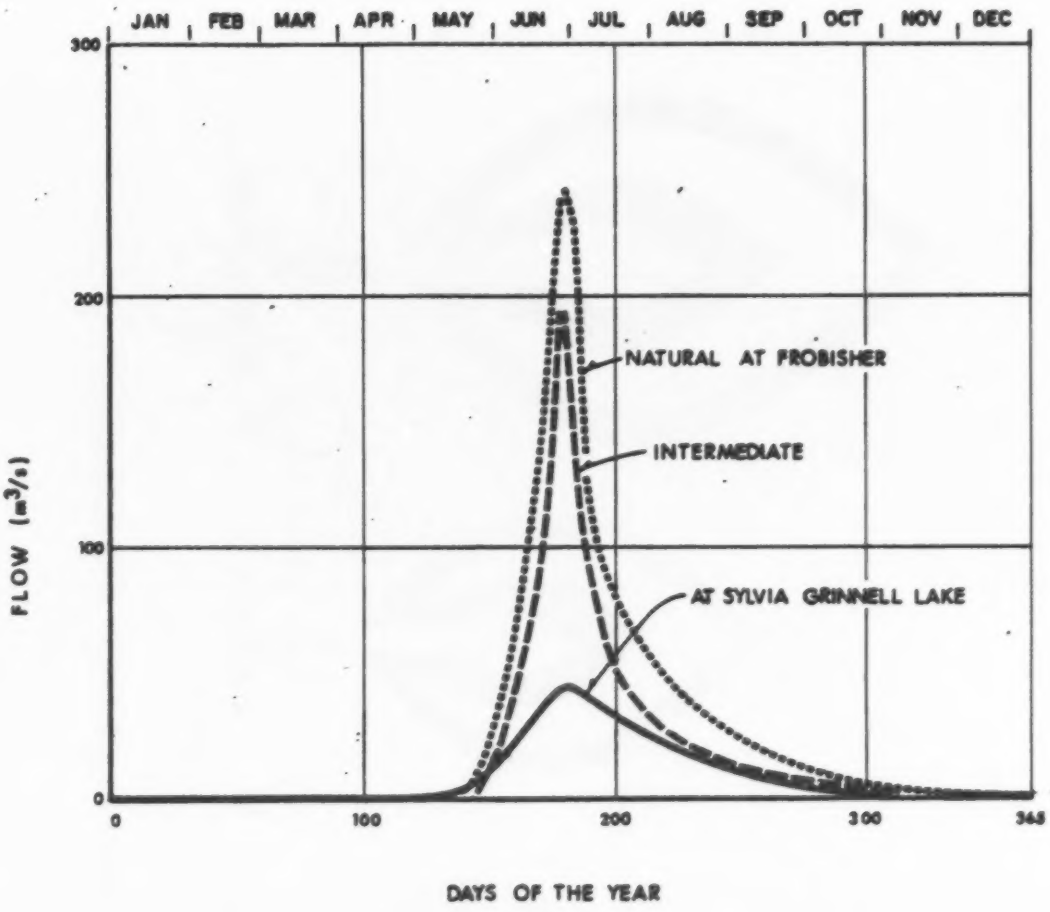
FROBISHER BAY DEVELOPMENT

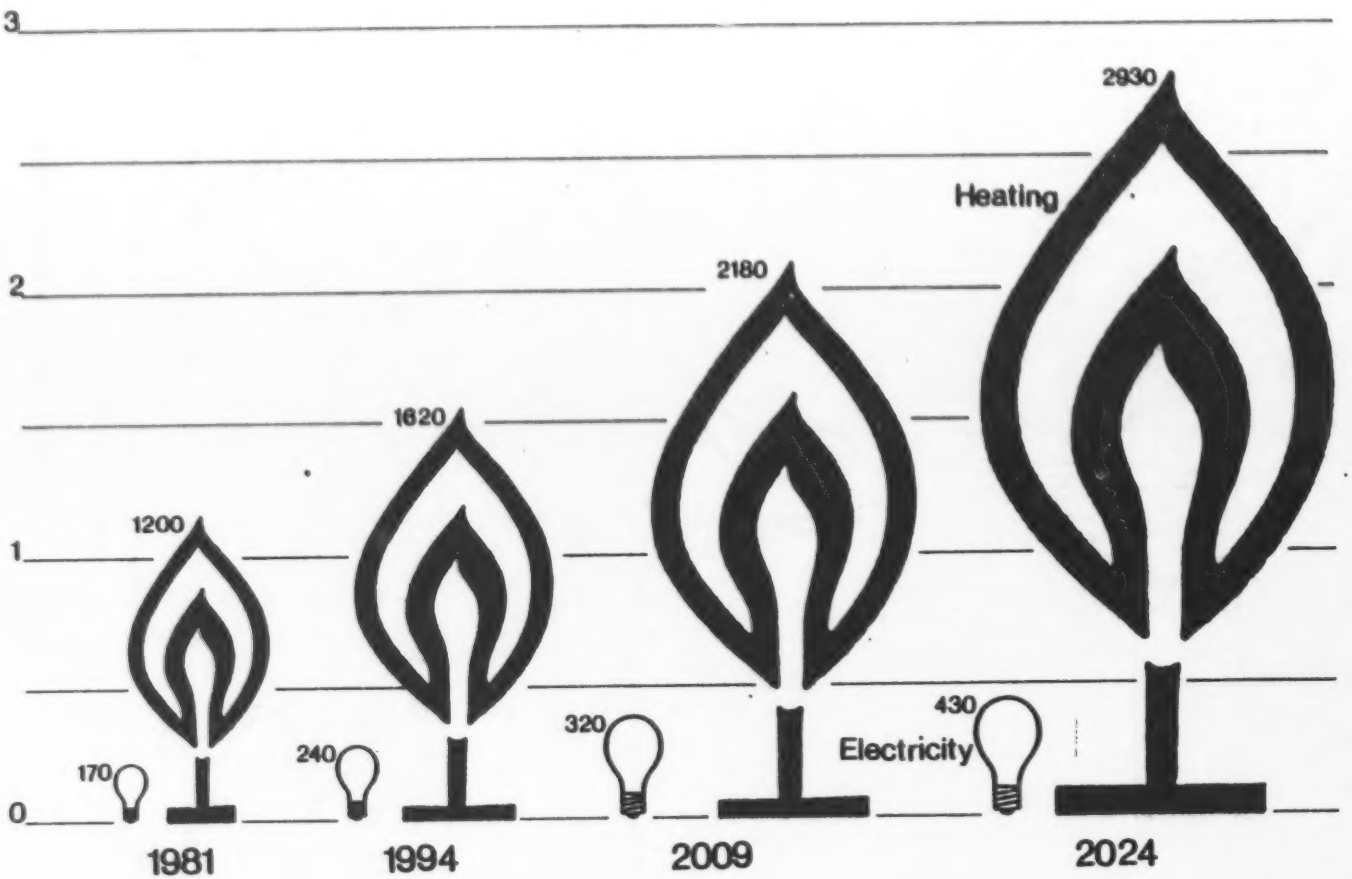
FIGURE 5.4



AVERAGE AT LAKE OUTLET 9.34 m^3/s

AVERAGE AT FROBISHER 24.2 m^3/s

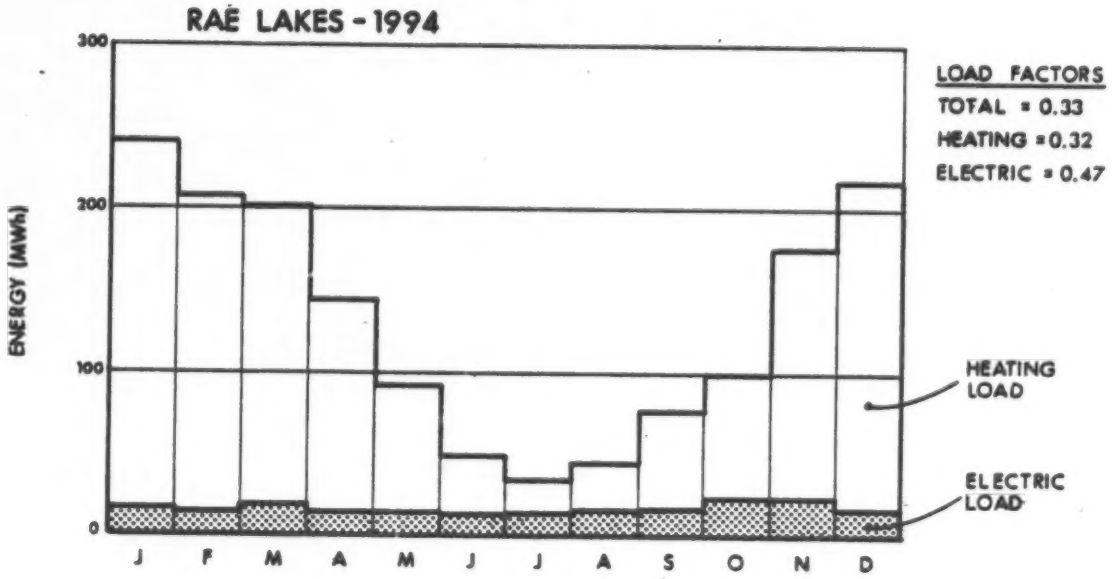
AVERAGE DAILY FLOWS
SYLVIA GRINNELL RIVER



RAE LAKES - ANNUAL ENERGY CONSUMPTION

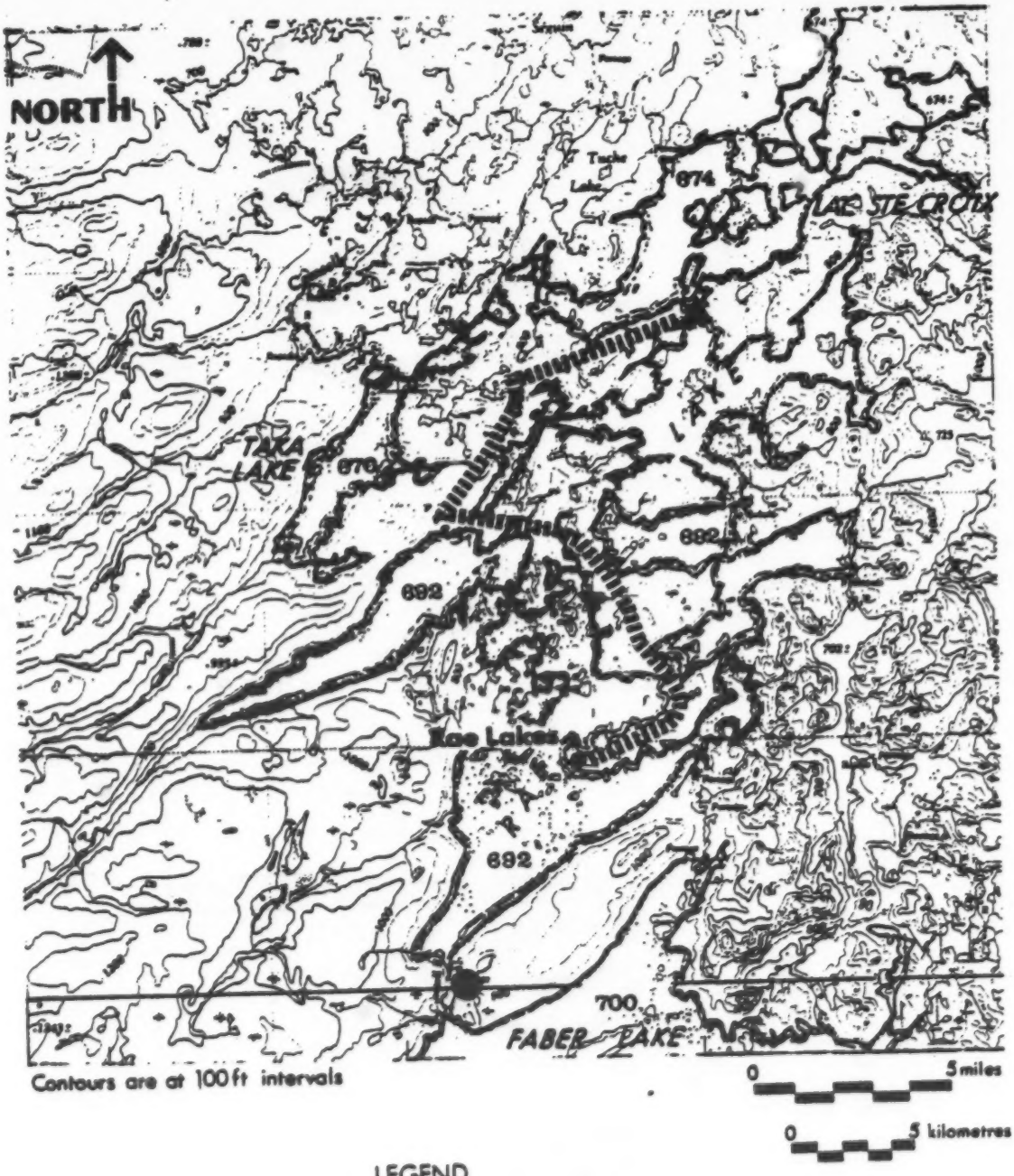
FIGURE 8.1

FIGURE 6 2



RAE LAKES - 1994
MONTHLY LOADS

FIGURE 6.3



LEGEND

- DAM & POWERHOUSE
- CONTROL STRUCTURE
- TRANSMISSION LINE
- RAE LAKE COMMUNITY

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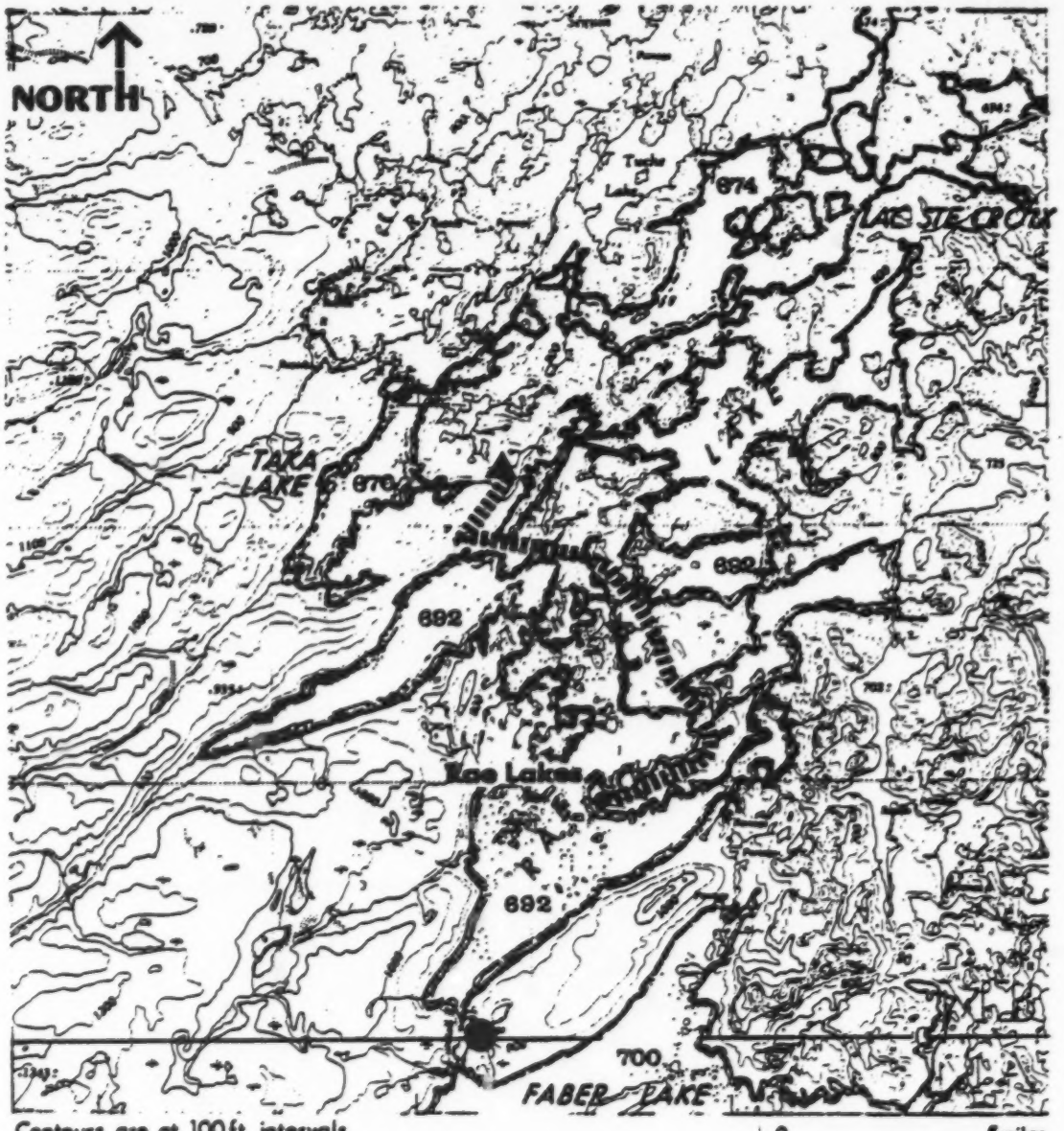
RAE LAKES
RAE LAKE / LAC STE CROIX DEVELOPMENT

FIGURE 6.4



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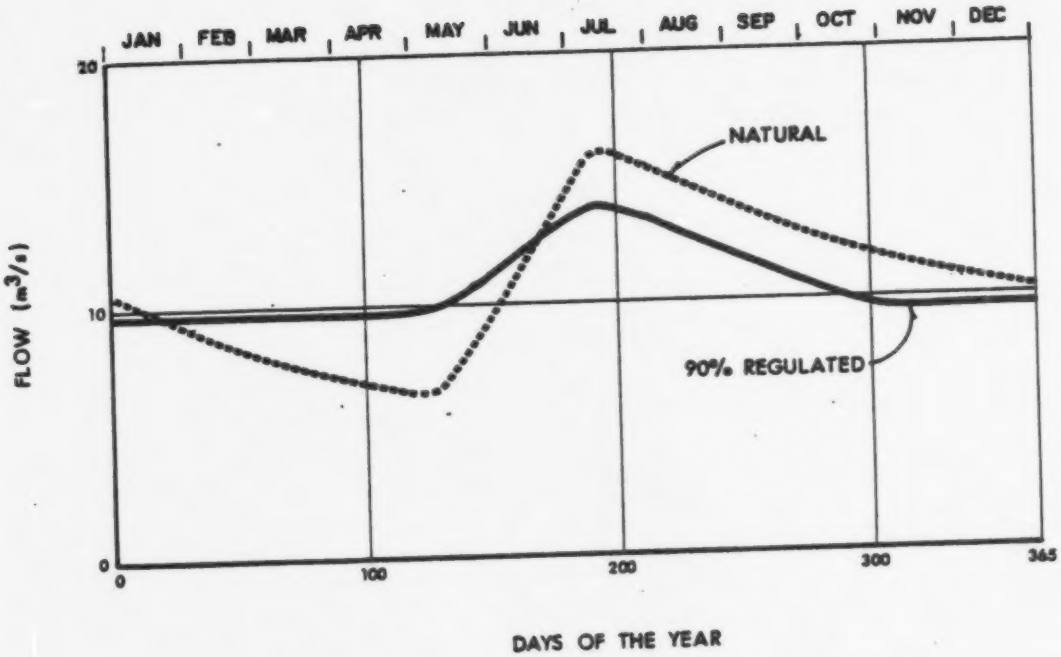
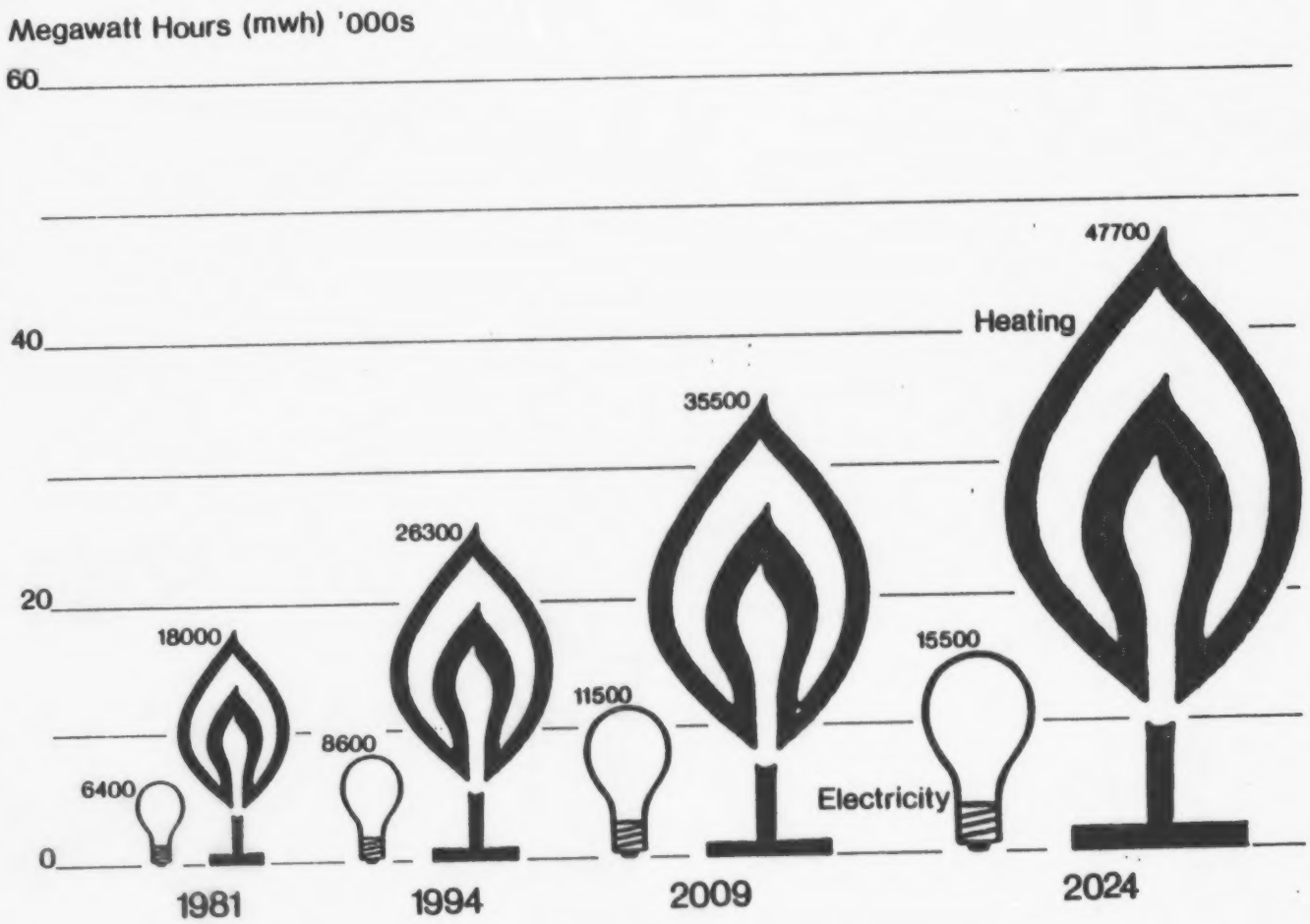
RAE LAKES
RAE LAKE / TAKA LAKE DEVELOPMENT

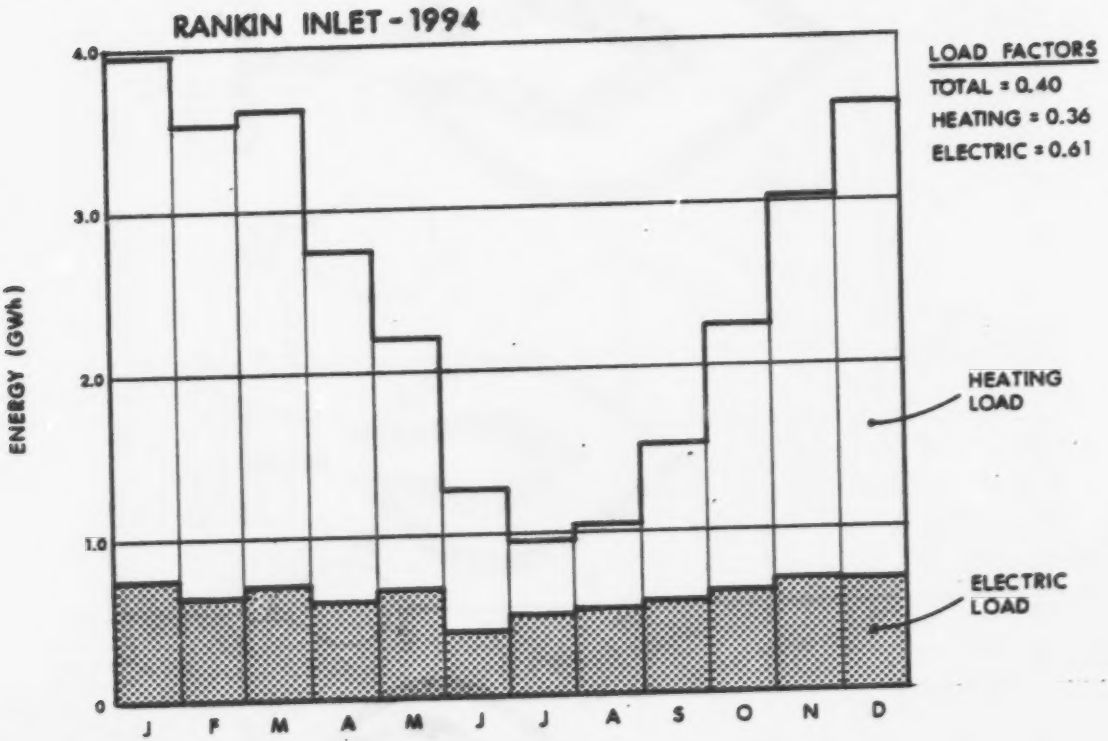


AVERAGE DAILY FLOWS
CAMSELL RIVER AT RAE LAKES



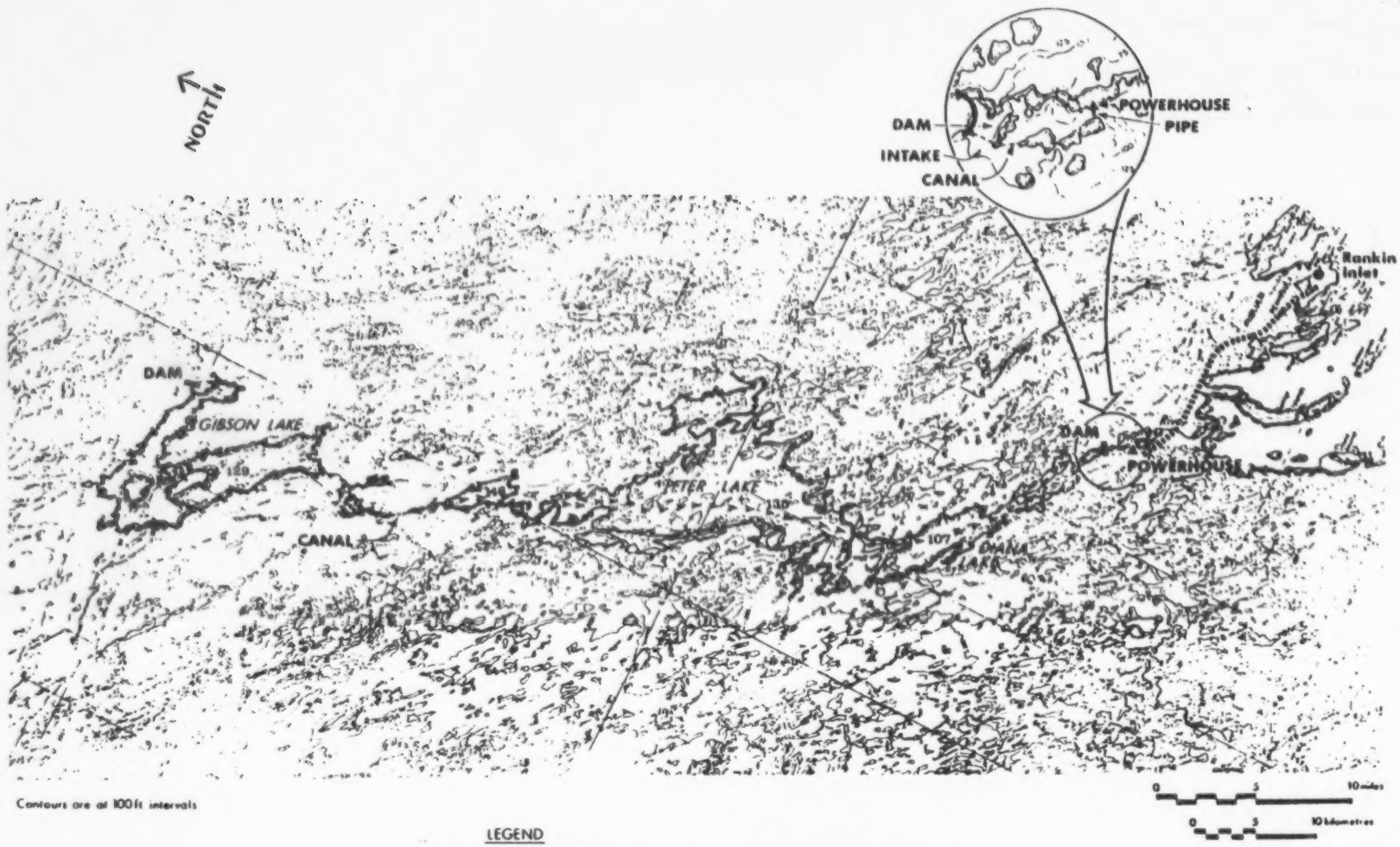
RANKIN INLET : ANNUAL ENERGY CONSUMPTION

FIGURE 7.1



RANKIN INLET - 1994
MONTHLY LOADS

FIGURE 7.3



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RANKIN INLET DEVELOPMENT

FIGURE 7.4

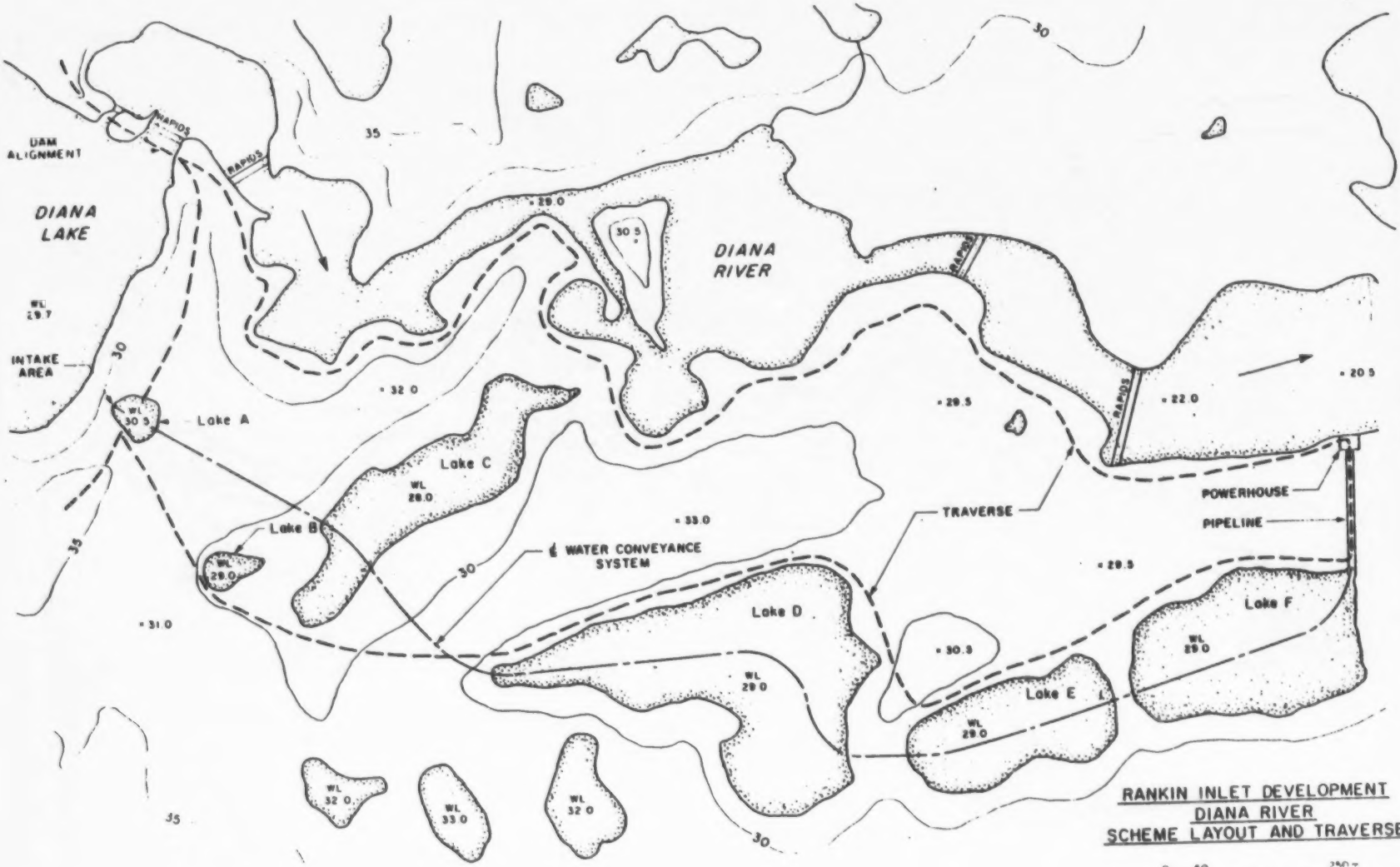
DAM ALIGNMENT
DIANA LAKE
DIANA RIVER
RAPIDS
RAPIDS
RAPIDS
RAPIDS
INTAKE AREA
WL 29.7
WL 30.5
Lake A
Lake B
WL 29.0
Lake C
WL 28.0
WATER CONVEYANCE SYSTEM
TRAVERSE
POWERHOUSE
PIPELINE
Lake D
WL 29.0
Lake E
WL 29.0
Lake F
WL 29.0
WL 32.0
WL 33.0
WL 32.0
35
30
30.5
32.0
29.5
22.0
20.5
33.0
29.5
31.0
30.3
RANKIN INLET DEVELOPMENT
DIANA RIVER
SCHEME LAYOUT AND TRAVERSE
0 50 250

FIGURE 7.5